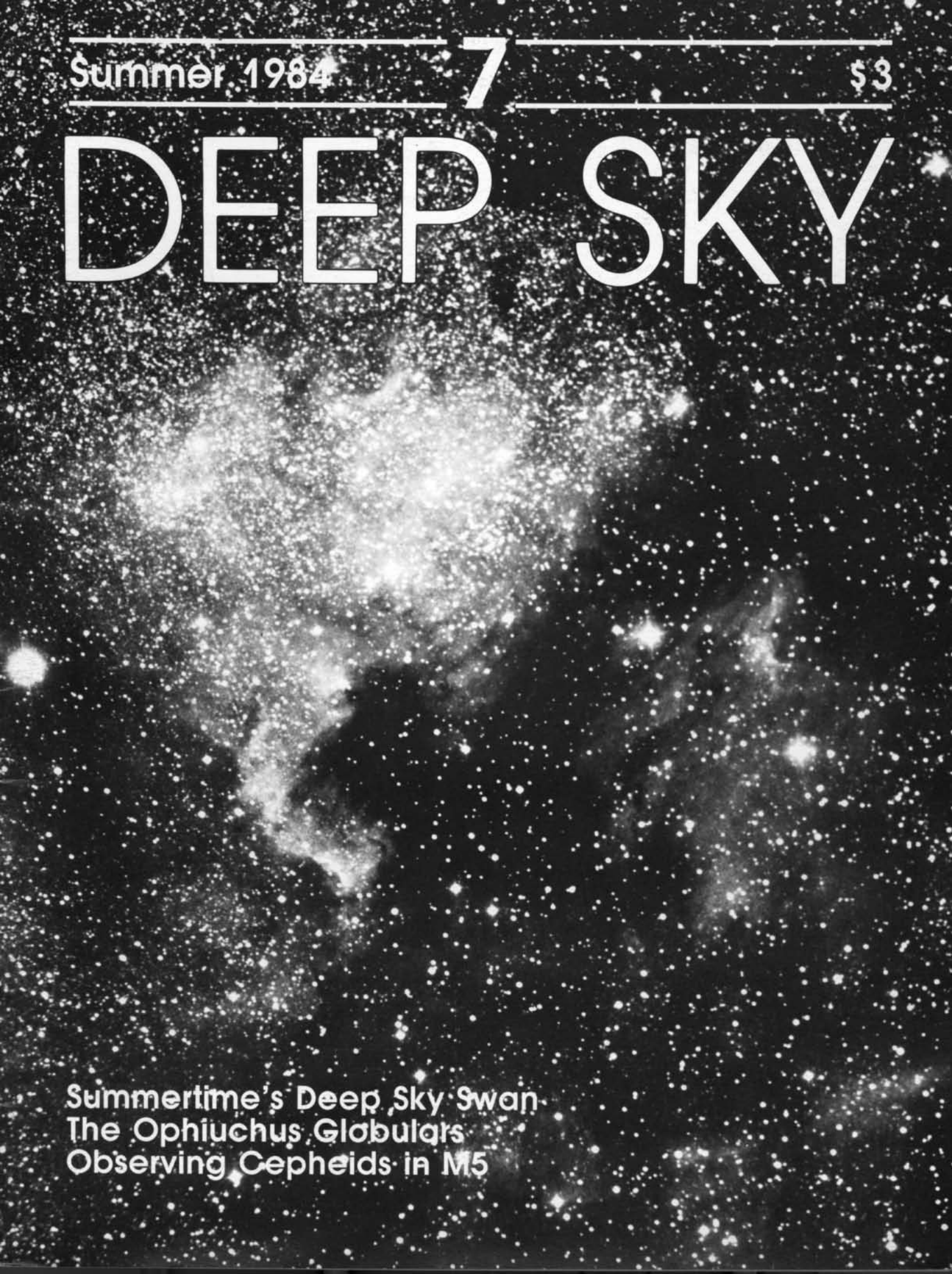
Summer 1984 7 $3

DEEP SKY



Summertime's Deep Sky Swan
The Ophiuchus Globulars
Observing Cepheids in M5

Letters to DSM

Low Surface Brightness Observing

Dave / I'd like to jump into the fray concerning Jack Marling's letter on magnitudes and surface brightnesses of galaxies (DSM 6, "How Bright is That Galaxy?"). The integrated magnitude of 12.2 cited in *Burnham's Celestial Handbook* for NGC 891 comes from the Shapley-Ames catalogue of 1930 (it is not just a guess, as you suggested). The Shapley-Ames magnitudes are well-calibrated eyeball estimates from small-scale blue-sensitive Harvard patrol plates. Gerard de Vaucouleurs found that these magnitudes are still useful though fraught with systematic errors which vary with the size, type, and magnitude of the galaxy in question. A large, moderately low surface brightness object like NGC 891 is usually listed rather fainter than it should be. In the introduction to the *Second Reference Catalogue of Bright Galaxies* (RC2), de Vaucouleurs shows how the old Harvard data can be placed on the standard B scale of the UBV system. Both the old and corrected data are given in the RC2 for Shapley-Ames galaxies. For NGC 891, the original value of 12.2 is corrected to B = 10.76 (that second decimal is not too significant).

From a combination of photographic and photoelectric photometry of the galaxy on the UBV system, an integrated of B = 10.90 can be derived, giving us a visual (V) magnitude of 10.0. This is the total light from the galaxy extrapolated to infinite diameter in an analytical way; the procedure is outlined in the RC2, and is widely used in the recent literature concerning photometry of galaxies.

Jack is correct in pointing out that neither B nor V matches the response of dark-adapted human vision. The visual peak wavelength is indeed roughly halfway between B and V, but the eye responds to most of the wavelengths of both photometric passbands. I gained my experience using B magnitudes out of the RC1 and RC2, but V appears to be just as consistent providing you adjust for the fact that galaxies are typically three-quarters of a magnitude brighter in V. I see no particular need for splitting the difference between B and V to get a "visual" magnitude, though it is a reasonably valid approach. You are stuck where there is a B magnitude only, as in the case of corrected magnitudes from the Shapley-Ames or Zwicky catalogues.

Now for surface brightnesses. Having discovered early the utility of the data in the RC2, I'm quite comfortable with the integrated magnitude/surface brightness combination and what it means at the eyepiece in terms of the difficulty of a specific object. A fundamental point to make about surface brightness magnitudes is that — for galaxies at least — they are *independent* of integrated magnitudes. This is because galaxies with faint integrated magnitudes tend to be very small: their brightness per unit area remains high. NGC 2805, for example, one of a group of galaxies in Ursa Major, is a difficult object in a 12.5-inch scope

See Letters, page 4

Back Issues of *DEEP SKY MONTHLY*

Before there was DEEP SKY magazine, there was *Deep Sky Monthly*!

Before AstroMedia Corp. — publishers of ASTRONOMY — began publishing DEEP SKY, it existed as a 20-page monthly magazine for deep-sky observers, published by amateur astronomer Dave Eicher in Oxford, Ohio. *DSM* started out as a mimeographed newsleter in June 1977, and by March 1980 became a glossy magazine, complete with observing tips, maps, charts, astrophotos, and articles for observers and photographers in tune with the current state of deep-sky astronomy. The magazine ceased publication with the May 1982 issue, after five years — 60 issues — of production. Now you can buy back issues of *Deep Sky Monthly*, while they last, in a "publisher's closeout" of the *DSM* inventory. The main article in each issue is listed below: other features, illustrations, and articles also appear in each issue. To order, send $2 for each back issue you mark on the form (or on a copy of the form), and be sure to list second choices if some issues sell out before you get your copy.

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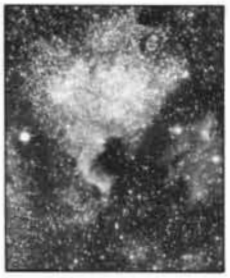
DEEP SKY 7

The magazine for deep-sky observers and astrophotographers

Summer 1984
Volume 2, Number 2



Cover: The North America and Pelican Nebulae, NGC 7000 and IC 5067/70, photographed by Paul Roques; 4-inch f/2.6 Schmidt Camera, hypersensitized TP 2415, 35-minute exposure.

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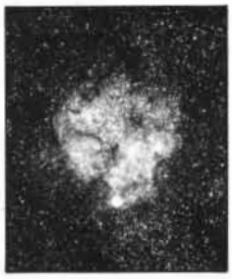

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6 Summertime's Swan Song

by Phil Harrington

Cygnus the Swan, flying high overhead and immersed in the rich northern summer Milky Way, is one of the deep-sky observer's favorite hunting grounds. Here lie bright galactic star clusters, double and variable stars, all shapes and sizes of planetary nebulae, and some of the finest — and most elusive — examples of emission and reflection nebulae. Regardless of your experience or equipment, Cygnus offers many hours' worth of impressive deep-sky views.

16 The Ophiuchus Globulars

by Jim Meketa

Because of our location about 10 kpc out from the Milky Way's center, most globular clusters — which live in a halo centered on the Galaxy's nucleus — appear in the sky toward the region of Sagittarius, Scorpius, and Ophiuchus. This article showcases 19 clusters — the Ophiuchus globulars — and reveals that each has a distinctly individual character and unique appearance.

22 Observing Low Surface Brightness Objects, Part 2

by Jeffrey Corder and David J. Eicher

Last issue we looked at 16 famed deep-sky objects of winter and spring skies, each with a reputation of being notoriously difficult to observe — so-called low surface brightness objects. Contrary to popular belief, many of these objects are within the range of amateur instruments under dark skies. With this issue we conclude the series, looking at the low surface brightness objects in the summer and fall skies — 25 in all.

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— its visual magnitude is 11.3 and its mean surface brightness is 14.9. In the same telescopic field, NGC 2814 shines at only visual magnitude 13.8 and, with a surface brightness of 13.1, is a much easier object. This seeming contradiction arises because NGC 2805 is a large face-on spiral like M101, while NGC 2814 is a compact irregular. In the ideal case, the magnitude of the faintest observable galaxy in any telescope would exactly match the stellar magnitude limit. But in practice even the faintest have some angular size and this brightens the limit. (Incidentally, at Zwicky magnitude 15, or V magnitude 14, galaxies are usually about 20″ across in a 12.5-inch scope.)

My observing experience has been that for each aperture there is a fairly well-defined limit on galaxies in terms of both integrated and surface brightness magnitudes. Galaxies are invisible beyond some "integrated" limit, but objects brighter than that limit will also be invisible if their surface brightnesses are fainter than some other value. I have found these limits to be consistent with the change in limiting stellar magnitudes for apertures up to 12.5 inches.

Rather than reveal what those numbers are, I would like to propose a project for the burgeoning readership of *Deep Sky*. Simply, what is the toughest galaxy for your telescope? Send in its designation (or perhaps that of several which are similarly difficult), and we'll see if there's a consistent limit as a function of aperture. Don't worry about not having a copy of the RC2, since the relevant data can be collected afterward. In your report, include the telescope's aperture and the magnification you used. Those with large (16-inches and up) Dobsonians ought to restrict their viewing for this project to well-studied clusters of galaxies: there aren't many field galaxies with photometry faint enough to give your instruments a tough challenge from a dark site. (Check the Webb Society's *Handbook*, volume 5, for some good clusters.) Remember that we'll want to test surface brightness limits and integrated magnitudes, so observe both large, low surface brightness objects as well as tiny , faint galaxies. If you want to try this project and need some suggestions for good galaxies, drop me a line.

Brian Skiff
421 West Aspen
Flagstaff, AZ 86001

Planetary Nebulae and You

Dear Dave / The Spring issue of *Deep Sky* was superb! Dave Kratz' article on observing planetary nebulae was ideal, as planetaries are enjoyable deep-sky targets even from light-polluted areas — largely because of their relatively high surface brightnesses. Under a good, dark sky, much more detail can be seen in planetaries than the article suggested. For example, NGC 3242 in Hydra is a fine sight in a 17.5-inch scope from my backyard in Livermore, California. At 220x and 420x, the central "eye" design was easy with a bright ovoid inner ring, central star "iris," and faint outer envelope of nebulosity. The same double structure is evident in NGC 7662 in Andromeda, NGC 1535 in Eridanus, and NGC 2392, the Eskimo Nebula in Gemini.

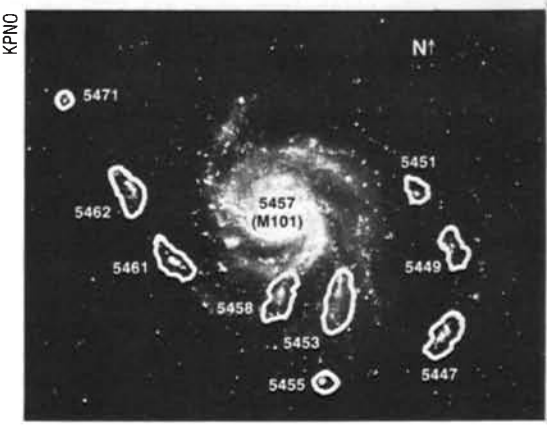
At the other end of the scale are the low surface brightness planetaries, such as NGC 7293, the Helix Nebula in Aquarius. From my dark sky site at Digger Pines, California, the Helix is relatively weak and is helped tremendously by using a good nebula filter, which causes its ring shape to "pop" out. NGC 246 is another large, ghostly planetary; it contains four bright stars within its incomplete ring of hazy gas.

As one involved with the production of nebula filters, I am quite interested that apparently some planetaries invisible without nebula filters are visible with them. Brian Skiff recently mentioned the tiny planetary Minkowski 1-18, just ½° northwest of the bright planetary NGC 2438 in the open cluster M46. Brian saw it easily with a 24-inch reflector and asked me if I could see it with my 17.5-incher. With a UHC filter, I just glimpsed it with averted vision.

Jack B. Marling
Lumicon, Inc.
2111 Research Drive
Livermore, CA 94550

Dear Jack / Thank you for the kind comments. I'm certain that under dark California skies you saw a good bit more detail than was described in Dave Kratz' article. When I edit such articles, I have an unusual amount of flexibility in claiming what can be seen in such-and-such a telescope. The two major factors of telescope aperture and type, and sky transparency and darkness, work in deep-sky observing as "aces in the hole," and they dramatically change what is visible in what telescope, and where. Assuming that most of the readers have telescopes in the 6-inch to 14-inch range, and live in reasonably good — but not ideally dark — locations, I think we provide appropriate information. I shoot for a happy medium and take it as being inevitable that some people will see slightly less or more, depending on instrument and sky. I've been a number of times to the Texas Star Party in western Texas, the Mojave Desert in southern California, the plains of central Arizona, and a number of other places where the sky is black and a big scope showed me an unbelievable amount of detail. But I don't want to base what readers can see on absolutely top-notch conditions — or 95% or more of the readership, not privileged with a really dark observing site, will not see what is being described. On another note, Jack, I took your UHC and Deep-Sky filters out with me and my 17.5-incher for two all-night observing runs this week, and I am speechless. From a site about 30 miles southwest of Milwaukee, particularly the UHC filter made all types of nebulae jump right out at me. It increased the apparent contrast 100% and converted weak, grainy "suspected" nebulosity into a bright, distinct image. Congratulations on producing the finest nebula filter I've used! — D.J.E.

KPNO



Gas clouds in M101 by NGC number

Messier 101 Errata

Dear Dave / In the letters column in *Deep Sky* 5, you gave incorrect identifications for the gas clouds in the Sc-type spiral M101 in Ursa Major. A few of these HII regions are visible in large amateur telescopes, primarily the ones with NGC numbers. I've included with this letter the correct identifications for gas clouds in M101, provided by the late William C. Miller of Hale Observatories.

Jeffrey Corder
Box 1082
Asheville, NC 28802

Murphy'slaw

Dear Dave/After reading David Healy's excellent article in DEEP SKY 6, "Astrophotography: Shooting Through the Scope," I simply had to reply to his closing sentiments which stated that Murphy's Law invariably messes up all astrophotographs.

Who is this "Murphy" I never saw,
spoiler of photos, writer of law?
Rivets lenscaps in place,
pokes your 'scope in your face,
his rule might as well be "Cole'slaw."

Whether I cannot or whether I can
see Neptune, Lyra, Aldebaran;
whether clouds, whether dew-

frozen foot in my shoe:
I blame the whether woman (or man).

With ISO 1600, dark skies and devotion,
simple PROBLICOM search for a nova explosion,
short optics tracking the Milky Way,
will allow any starlover forever to say:
"Astrophotography IS poetry in motion!"

To David Healy with kind regards.

Ben Mayer
1940 Cotner Avenue
Los Angeles, CA 90025

Faint and Challenging Deep Sky Objects

Dear Mr. Eicher / In the last issue you asked whether or not anyone has observed the faint supernova remnant IC 443 in Gemini. I've seen it in my 16-inch reflector a number of times, using a Lumicon UHC filter. At 90x it appears as a short arc, about 20′ long and with an apparent thickening at one end. Under Arizona skies it is relatively easy to locate and was even detectable as a brightening in the field without a filter.

Chris Schur
Star Rt. Box 952
Black Canyon City, AZ 85324

Dear Dave / Regarding the article "Low Surface Brightness Objects" in DSM 6, it should be pointed out that often faint objects show locally brighter "spots" of either lower or higher brightness, and these spots vary irregularly over the surfaces of many objects. In this case, the entire object may not be visible, but its brightest parts may be.

Galaxies, for example, have bright nuclei; IC 342 in Camelopardalis fits into the class wherein its nucleus is relatively easy but other parts of it are extremely difficult. Emission and reflection nebulae are often brightest near their edges or near illuminating stars. NGC 2264 in Monoceros, the nebulosity surrounding the Cone Nebula, has a bright extension about 10′ southwest of S Monocerotis, and it includes three or four bright stars. The difficult emission nebula IC 410 in Auriga, involved with the bright cluster NGC 1893, shows up best on the northwest side of the cluster.

I am looking forward to part two of the article.

Steve Gottlieb
155 San Carlos
El Cerrito, CA 94530

Dear Steve / You are quite correct that the issue of surface brightnesses is rather more complicated than we presented it in the article. By nature all astronomical objects vary in brightness from part to part, but the state of data is so bad that even mean surface brightnesses do not exist for most objects. In most cases the mean surface brightness must be relatively close to any variation, either down or up, and so for the moment I will be happy to collect mean surface brightnesses and more or less ignore the variations. (What you really want for determining whether or not something can be seen is the "high-end" surface brightness — the magnitude per unit area of the nebula or galaxy's brightest parts.) Given enough time, perhaps amateurs can develop similarly calibrated visual photometers for directly measuring surface brightnesses with large telescopes; this would allow you to make a plot of how surface brightness changes over the face of a deep-sky object. In the meantime, you need not continue looking forward to part two of the LSB article — it's on page 22!
— D.J.E.

Color in M42

Dear Sir / I have been following the ongoing debate regarding color in M42 with interest. I live near Ashland, Wisconsin — near the southern shore of Lake Superior — where the sky is dark. With my 10-inch Newtonian, M42 always appears pale green at low to medium powers. On one recent occasion I used 135x and saw a definite bright blue tint in the nebulosity. My wife, who is not an observer, saw the color as well.

Jay Moynihan
Box 253
Ashland, WI 54806

Inside View

The Joys of Summer Observing

Summer is back, and once again it feels great standing out under the stars, free from winter's cold and spring's showers. Last week was exceptionally lucky: five nights of crisp seeing and steady transparency, tempting me to load my 17.5-inch reflector into my van and make the 45-minute drive to reasonably dark skies.

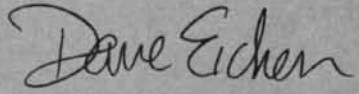
Observing during the summertime is not only relatively comfortable (even with mosquitoes), but many of the finest deep-sky objects are well-placed for viewing. Take the constellation Cygnus, for example: here lie the North America Nebula, the Veil Nebula, brilliant Albireo, and about 70 other objects easily viewed with backyard telescopes. This issue's lead article by Phil Harrington presents the best objects of Cygnus the Swan, and should keep you busy hunting them down.

Also in this issue Massachusetts observer Jim Meketa describes in detail the globular clusters of Ophiuchus — 19 in all. A number of observers I've talked to claim that observing globulars is boring because "they all look the same." Those observers tell me more about themselves than the clusters when they say that; Jim's article should convince you that even in the same region of sky globular clusters are distinctly different from one another. Some are quite different. Messier 5, the sky's eighth brightest such object, contains two Type II Cepheid variable stars (W Virginis stars) which are bright and well within the range of amateur scopes. Included in Jim's second article is a large-image-scale finder chart enabling you to track down the variables in relation to field stars near the cluster's nucleus.

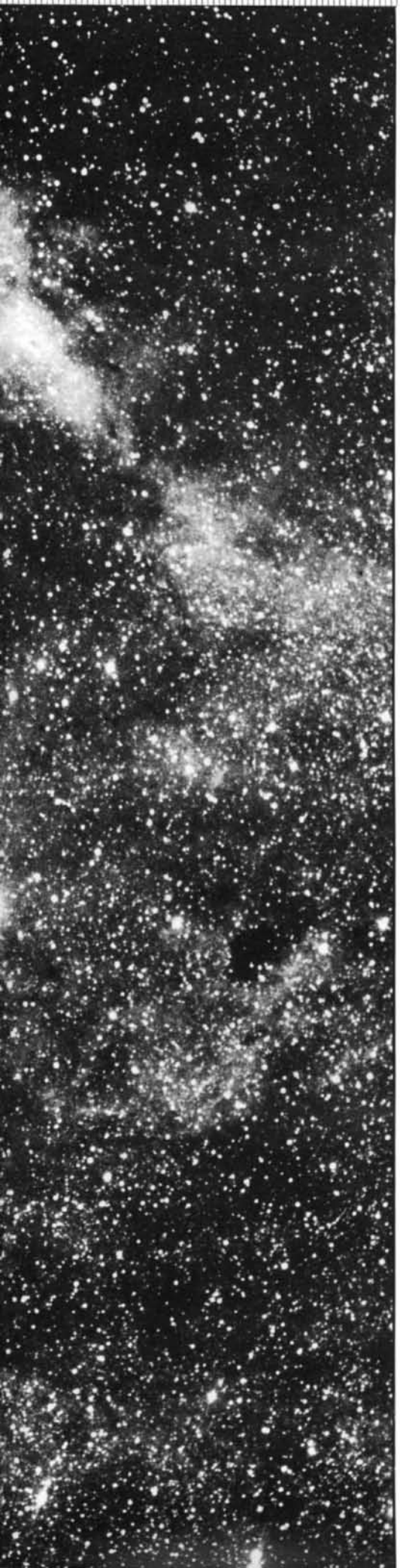
With the advent of large telescopes and good nebula filters, so-called low surface brightness objects are fast becoming widely known about and observed. In part two of our article, Jeff Corder and I look at 25 such objects in the summer and fall skies. Note that we do not have observations of a few of the objects — let us know how you do with finding these elusive telescopic targets.

Indeed *Deep Sky* 7 contains a goodly number of challenges: can you find the emission nebulae IC 59 and IC 63 in Cassiopeia, objects of surface brightness 15? Can you follow the regular luminosity cycles of two Cepheid variables lying nearly 8 kiloparsecs away from us? Can you spot the infamous nebulosities of Cygnus, which demand a dark sky? We'd love to hear from you this summer — hear about your observing or your thoughts about *DSM* or astronomy in general. But don't knock yourself out — remember that warm, comfortable summer evenings are back. So enjoy them!

Warm regards,



Dave Eicher
Editor



Summertime's Swan Song

by Phil Harrington

All images in this article, save the facing page, have south up, west at left.

Flying high overhead during the months of June through September is the spectacular constellation Cygnus the Swan. With the summer Milky Way passing through it, Cygnus contains a great variety of deep-sky splendors to entice the observer. Indeed, regardless of your telescopic equipment, Cygnus holds something for you.

One of the finest binary jewels in all the heavens forms the Swan's beak: **Albireo**, also known as Beta (β) Cygni. The primary star is type K3, radiating a distinctive yellowish glow, while the hotter, though fainter, companion is type B8, shining a contrasting blue. It is an easy target for small telescopes, and even a good pair of binoculars will reveal the two suns, separated by 34″, which comprise the system. Try using a long focal-length eyepiece to enhance the pair's colorful contrast and slightly defocus the image to make the colors stand out further.

Another double star worthy of attention is **Delta** (δ) **Cygni**. As it has a separation of just over 2″, owners of 3- to 4-inch telescopes will find this a good test object. Indeed, it may prove a difficult trial for larger telescopes as well, owing to the fact that the magnitude 6.5 companion is positioned coincident with the first diffraction ring of the third magnitude primary. Unless viewed under very steady seeing conditions, the companion may be undistinguishable. In his *Celestial Objects for Common Telescopes*, T.W. Webb noted that resolving the pair was frequently easier in twilight than in a dark sky. Do modern-day observers still find this to be true?

The star Gamma Cygni, also known as Sadr, lies in the plane of the Milky Way and is surrounded by nebulosity. At center we see IC 1318's glowing banks of gas, which show as subtle streamers in large telescopes. Photo by Brant Nelson; 8-inch f/1.5 Schmidt camera, hypered TP 2415, 20-minute exposure.

About two degrees northwest of Delta Cygni is **NGC 6811**, a 10th magnitude open cluster spread over a 10′ diameter area. My 8-inch f/7 Newtonian reflector reveals a faint, but rich gathering of about thirty stars, including several double stars.

Further north, near **Theta** (θ) **Cygni** (itself a triple star with components of magnitudes 5, 13, and 11 separated by 4″ and 48″, respectively), is the long period variable star **R Cygni**. Over its 426 day period, R Cygni fluctuates between magnitudes 7.4 and 13.9. This wide variation makes it ideal for beginners. The deep ruddy glow of the variable contrasts beautifully with bluish Theta visible in the same field of view. Nearby is **RT Cygni**, another long-period variable. Observers with smaller instruments may find this a more satisfying star to watch. As it varies from magnitude 7.3 to 11.8, its active range lies within the grasp of a 3-inch.

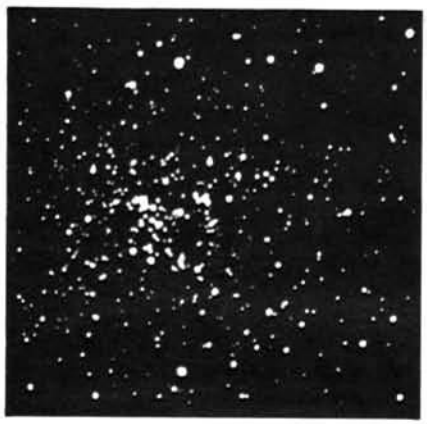
NGC 6826, just west of 16 Cygni, is an easy planetary nebula. The "Blinking Planetary," as it is popularly referred to, shines at 9th magnitude, and measures about 25″ in diameter. What makes it an especially interesting object is its visual appearance. Averted vision reveals the nebula's disk surrounding an 11th magntiude central star. However, when you view it directly, the nebula seemingly disappears, only to reappear when you glance away. The blinking effect can be seen in instruments of all sizes, but it is most striking in 8-inch or smaller scopes.

East of RT Cygni is a challenging planetary, to say the least. **NGC 6833** shines at an unimpressive magnitude 14, and is only 2″ in diameter. For most of us, a high-powered 12-inch will be required to glimpse it, although some observers have seen it with less. Take

Sketch by David J. Eicher

NGC 6992/5 8-inch f/5 SCT 35X

John A. Leader

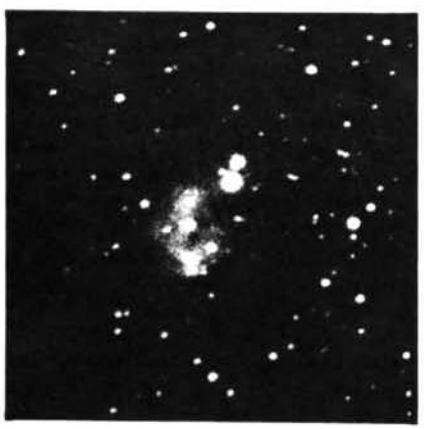


NGC 6819 8-inch f/10 SCT 60mm., 103a-F

Sketch by Debra J. Williams

Albireo 4-inch f/4 Newtonian 48x

Martin C. Germano



NGC 7008 8-inch f/10 SCT 50 min., 103a-F

great care to distinguish the nebula from the plentiful field stars!

Closer to the realm of "easy," yet still a difficult catch, is the planetary **NGC 6884**. Locating its field is not too difficult as Omicron (*o*) Cygni lies less than a degree away, but trying to spot the nebula is another matter. My notes recall a "very small, faint disk at 210x; nearly stellar at 54x."

Far more rewarding for those in the 6- to 8-inch instrument class is the open cluster **NGC 6866**. Spread over a 7′ field are some 20 stars of magnitude 11 and fainter, immersed in a glow of unresolved cluster members. My first observation of this group was in 1973, when I noted that the cluster took on a triangular shape, but subsequent sightings fail to note this appearance.

One of the most impressive open clusters in Cygnus is **NGC 6819**. Even a 2-inch will reveal this flickering mass of faint stars. A dozen suns surrounded by nebulosity will be seen in a 6-inch. An 8- to 10-inch will increase the count to about two dozen stars, all compressed into a 5′ field. About 150 suns in total populate NGC 6819.

Charles Messier's catalogue contains only two objects within Cygnus. One is **M29** (NGC 6913), positioned nearly 2° south of Gamma (γ) Cygni. (The other is M39, which we'll get to later.) Messier discovered this sparse open cluster in the summer of 1764. The best view is through binoculars, a finder scope, or a rich-field telescope (RFT), since its dozen members scatter loosely over a 5′ area. As you increase magnification, the cluster's beauty will diminish. Through large instruments, M29 is practically unrecognizable from the neighboring star fields. Studies indicate that M29 contains about 1000 times the density of dust found in the Milky Way. If it was not for this obscuring matter, M29 would be a far more impressive sight.

Just north of Gamma Cyg is **NGC 6910**. This small open cluster shines at eighth magnitude, and contains about 20 ninth-magnitude stars. When viewed with low power, the group resembles an inverted letter "Y." This appearance was noted in both my 8-inch reflector, as well as in volume 3 of the Webb Society's *Deep Sky Observer's Handbook*.

Almost bordering NGC 6910 to the north is **Collinder 421**, a little-observed open cluster with 15 stars scattered over a 6′ area. **Collinder 419** is a brighter member from the same catalogue; on this object my 8-inch reflector showed a fairly compressed gathering of 14 faint points of light against the soft glow of other unresolved cluster members. For a more challenging cluster, try your luck with **Dolidze 5**, about 1.5° southeast of Cr 419. Here you will find a poor object, with only a half dozen stars, the brightest being magnitude 11. **IC 1311** is another small, faint open cluster. It is comprised of about eight stars ranging in magnitude from 11 to 13. While these clusters won't impress the "civilians" at star parties, any true-blue deep sky aficionado will find them worthwhile.

Clear, dark skies are a must for our next object. **NGC 6888** is a bubble-shaped filamentary cloud just south of the variable RS Cygni. To glimpse this apparition, first locate four 8th magnitude stars lying in a diamond formation (three are plotted in the *Sky Atlas 2000*). By using averted vision, you may spot 6888 stretching from the easternmost star, around the northernmost, and ending near the southernmost star of the diamond. Photographs reveal the full semi-circular nature of this probable supernova remnant which is "powered" by a hot Wolf-Rayet star.

Another faint cloud in the area of Gamma Cygni is **NGC 6914**. Once again, averted vision is necessary, even under excellent conditions. Volume 2 of the *Deep Sky Observer's Handbook* notes that there are actually three separate reflection nebulae in the immediate area. Can observers with very large telescopes detect all three? I have failed using my 8-incher, as all are difficult. Some observers, however, claim to have caught fleeting glimpses in 6- and 8-inch RFTs.

NGC 6874 is a moderately rich, compressed open cluster which is not shown on either the old *Atlas of the Heavens* or the *Sky Atlas 2000.* Undoubtedly this is because of its near imperceptibility on the Palomar Sky Survey, due to very dense regions of nebulosity or field stars. The *Revised New General Catalogue* defines open clusters of this nature as class 7 objects. Visually many can be seen, since most of the faint field stars lie well beyond the limiting magnitude of amateur instruments. When aimed at 6874, my 8-inch displayed about 20 stars across a 10′ field. Most of the stars are magnitude 12 and fainter, so wait for a truly clear night for the best view.

Between 29 and 34 Cygni lies **IC 4996**. The Webb Society's *Handbook* describes it as a "beautiful (open) cluster in a rich field." However, all I found was a small, sparse group. The 8-inch revealed only 7 stars, with a nice triple among them. *Burnham's Celestial Handbook* and other reference works ignore the object completely. Take a look at IC 4996 the next clear night, and judge for yourself. Why not drop us a note with your impressions?

Nearby is the elusive plànetary nebula **NGC 6881**. You'll probably find a 10 or 12-incher necessary for positive identification of this 14th magnitude, 5″ diameter disk. The largest amateur instruments may show the 15th magnitude central star. Somewhat easier is **NGC 6857**, which lies a little

less than 2° southeast of Eta (η) Cygni. Using a 12.5-inch f/5 reflector in Connecticut, I recorded it as a "very faint planetary; about 1′ diameter, nearly circular; central star suspected but unable to confirm; nebula about magnitude 13." One word of caution: NGC 6857 lies in a rich star field; a slow, meticulous search is the only way to find it. You'll have to use a similar approach with **NGC 6894**. The two objects are about equal in size and brightness, so chances are that if you can spot one, the other will show itself. However, don't expect to spot the 6894's central star; it is magnitude 17.

Another class 7 group is **NGC 6896**. Most observing handbooks tend to ignore this sparse open cluster, and with good reason. At its position, my 8-inch showed only a few scattered stars across a rich field, more resembling an asterism than a true cluster.

The open cluster with the largest apparent diameter in Cygnus is **NGC 6871**. Under ideal viewing conditions, it is visible to the unaided eye as a bright patch of Milky Way between Gamma and Eta (η) Cygni. It measures 40′ across — larger than the Full Moon — hence, low powers are a must. My 4¼-inch f/4 RFT provided a far superior view than the 8-inch. The former displayed about three dozen stars ranging in brightness from magnitude 7 to 12. A very attractive double, Σ2630, lies within the cluster. Curiously, 6871 is omitted from *Burnham's Celestial Handbook*, an unusual oversight.

From here scan 1.5° due east, where you will encounter another smaller open cluster. **NGC 6883** is a loose collection of about 24 stars, almost indistinguishable from the rich background. My notes sum up its appearance: "This is a cluster?"

About one quarter of the way from Eta Cygni to Albireo is **Chi** (χ) **Cygni**, a long-period variable with an unusually large magnitude range. At maximum, it may reach fifth magnitude, and become visible to the naked eye. Its light then fades at a fairly constant rate until, some 200 days later, it bottoms out at 13th magnitude. According to AAVSO predictions, maximum occurred in late May. Therefore, over the summer, Chi will slowly diminish to its minimum, due in mid-January 1985. Try monitoring the star over the months to come and see how well it follows the predictions.

Along the Cygnus-Vulpecula border lies the rich open cluster **NGC 6834**. Although it is not considered a bright object, I did spot it in an 8x50 finder. Upon closer inspection, you'll find about 25 stars resolved within a 6′ area. For the best view, switch to a medium-power eyepiece. NGC 6834 makes a good starting point for locating **NGC 6842**, a faint planetary nebula. What makes the latter notoriously difficult to spot is its low surface brightness: it is rated at 13th magnitude, but measures nearly 1′ across. A low magnification is best for finding its round disk, but when you find it, change to higher power to search for finer detail. Very large telescopes may reveal the 16th magnitude central star, given steady seeing.

Tucked away in the far northern corner of Cygnus is **NGC 6946**. This type-Sc spiral galaxy proves a challenge; visually, it is 10th magnitude, but it measures 15′ across. Due to its very low surface brightness, most observers will detect only the central nucleus — though its true spiral nature could perhaps be detected visually through instruments of 20-inch or greater aperture. Astronomers estimate the distance to NGC 6946 at 15 million light-years, which places it just outside the Local Group of galaxies. And while you're in this part of the sky, be sure to view **NGC 6939**, less than a degree to the northwest in nearby Cepheus. This is the richest open cluster in Cepheus, although it is often neglected by many observers. A moderate size telescope will show many of the 100 stars that make up this fine group.

Cygnus' best known sight is almost certainly the **Veil Nebula** complex, a fragmented supernova remnant about 2.5° in diameter. Since William Herschel discovered the brighter parts of the nebula in 1784, the Veil has proven a difficult test object for many an experienced observer. (See also "Observing Low Surface Brightness Objects", page 22, this issue.)

Brightest of the three main sections of the complex is **NGC 6992/5**, the eastern loop. It measures about 1° long, so be sure to use a wide-field ocular when you scan for it. Careful scrutiny is required to glimpse the delicate gossamer structure seen in photographs. Last summer, under superb conditions in Worthington, Massachusetts, Ron Woodland's 17-inch reflector offered a view that was breathtaking. The intricate filamentary pattern was easily and directly visible. That same evening, my 8-incher also revealed the complexity of the luminous cloud, though I had to use averted vision.

The westernmost section, **NGC 6960**, is bisected by the fourth magnitude binary **52 Cygni**, a foreground object. Woodland's 17-inch displayed a tangled glowing splinter of light, somewhat fainter than 6992, but still distinctly impressive. While searching for 6960, be sure not to overlook 52 Cygni itself. Even a 3-inch telescope resolves its orange and blue stars, of magnitudes 4.5 and 9.5, separated by 6.5″. Together, they offer a stunning contrast set against a rich field.

Between these two outer loops of the Veil lie a number of fainter clouds. All appear quite conspicuous in

Sketch by David J. Eicher

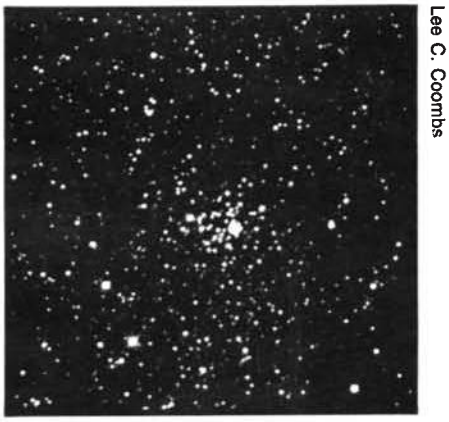
NGC 6960 8-inch f/5 SCT 35x

Martin C. Germano

NGC 6894 8-inch f/10 SCT 45 min., 103a-F

Sketch by Jim Garasich

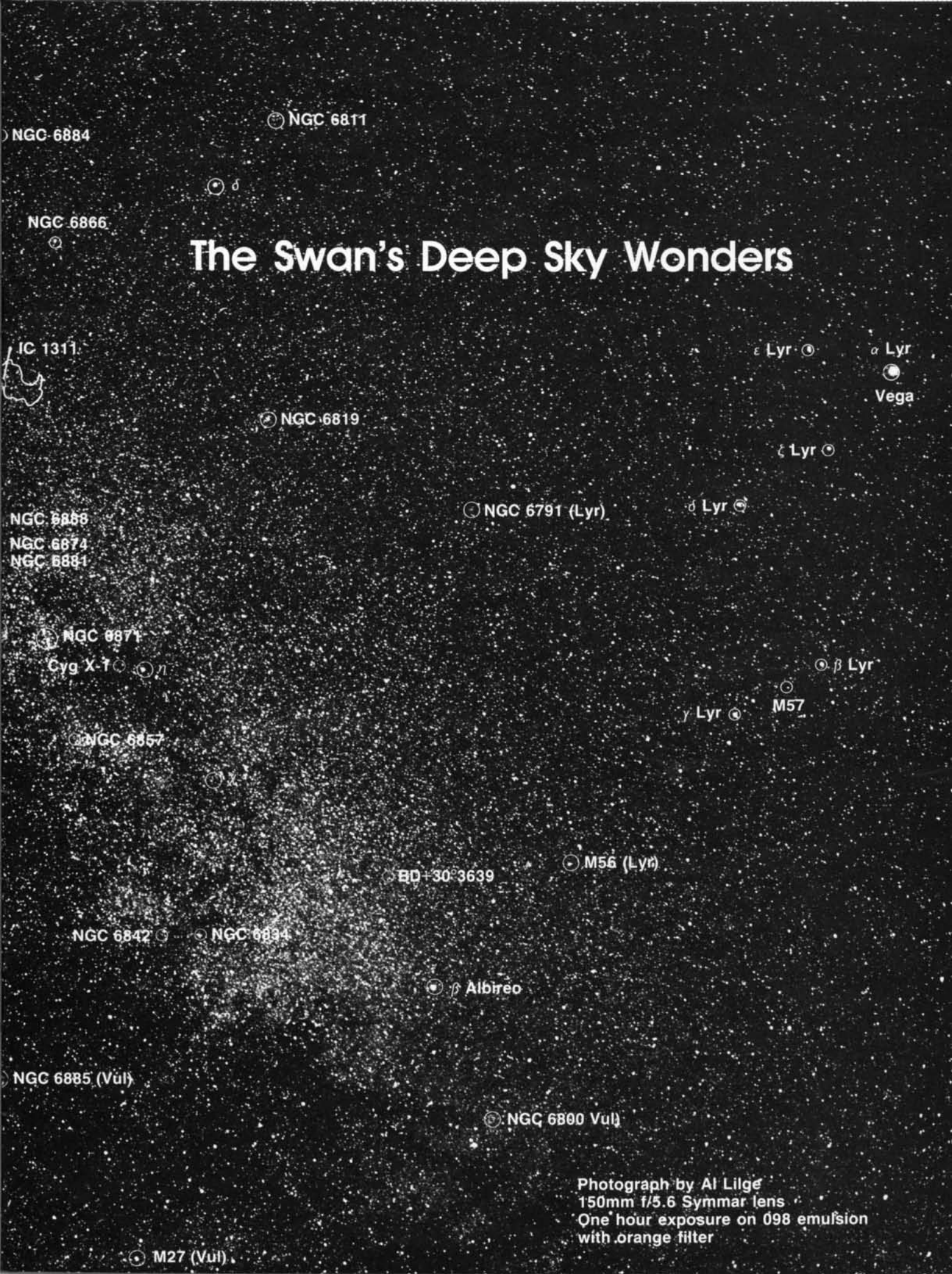
NGC 6866 4¼-inch f/10 Newtonian 64x



Lee C. Coombs

NGC 7062 10-inch f/5 Newtonian 10 min., 103a-O

IC 1369
NGC 7026
NGC 7086
NGC 7082
IC 5076
NGC 7062
NGC 7048
NGC 6997
IC 5117
SS
NGC 7000
North America Nebula
α Deneb
IC 5067/70
Pelican Nebula
NGC 7044
NGC 6910
Col 419
NGC 7027
IC 5068
NGC 6914
Humason 2-1
Col 421
IC 1318
Complex
61
Dol 5
γ Sadr
M29
IC 4996
NGC 6883
NGC 6979
NGC 6992
NGC 6995
NGC 6896
NGC 6960
Veil Nebula
NGC 6894
NGC 6940 (Vul)


NGC 6811
NGC 6884
δ
NGC 6866
The Swan's Deep Sky Wonders
IC 1311
ε Lyr
α Lyr
Vega
NGC 6819
ζ Lyr
NGC 6791 (Lyr)
δ Lyr
NGC 6858
NGC 6874
NGC 6881
NGC 6871
Cyg X-1
η
β Lyr
M57
γ Lyr
NGC 6857
χ
M56 (Lyr)
BD+30°3639
NGC 6842
NGC 6834
β Albireo
NGC 6885 (Vul)
NGC 6800 Vul
Photograph by Al Lilge
150mm f/5.6 Symmar lens
One hour exposure on 098 emulsion
with orange filter
M27 (Vul)

20 "Nonexistent" Objects in Cygnus

by Jim Meketa

In compiling the *Revised New General Catalogue*, Jack Sulentic and William Tifft attempted to locate all 7840 objects in J.L.E. Dreyer's original *New General Catalogue*, using as a primary reference the magnificent Palomar Sky Survey prints. Taken in both red and blue light with the 48-inch Schmidt Camera on Palomar Mountain, these plates show stars to magnitude 23 at a scale of 1′ per mm. Sulentic and Tifft were unable to match 20 of the original NGC entries for Cygnus with any visible object on the Sky Survey prints, leading them to classify these objects as "nonexistent."

The original NGC was compiled entirely from visual observations made and recorded manually before 1888, primarily by William and John Herschel — without, of course, the benefit of computers or deep-sky photography. The first edition of the NGC contained numerous errors, a fact which Dreyer acknowledged by including a careful list of all corrections found as appendices in each of his successive *Index Catalogues*. The final edition of the NGC is a very complete survey of the brighter deep-sky objects, and the descriptions closely match the views in large amateur telescopes.

That a work of such painstaking care as the NGC should contain 20 "phantom" listings for Cygnus alone seems unlikely. The Herschels were first-rate scientists as well as skilled and meticulous observers. It is easy to forget that a photograph, no matter how perfect the camera, is simply another abstraction of reality, as is the visual image. Perhaps the 20 "missing" objects are indeed missing, not from the sky but from the Palomar Sky Survey prints.

Fourteen of the 20 suspect entries refer to open clusters first noted by the Herschels. None are described by them as bright or exceptional, and all are located in the heart of the Cygnus Arm of the Milky Way, an exceedingly rich section of sky. Many areas of the Palomar Sky Survey plates here are so densely packed with faint star images that they are virtually opaque, and important details often get drowned in the clutter.

I would guess that at least half these objects can be found with a large amateur telescope. Several of the clusters sighted by the Herschels are described in detail, especially NGC 6856, 6989, 7037, and 7071. These are probably real galactic clusters, and should be relatively easy to locate. NGC 7054 is almost certainly a small planetary with a fairly bright central star, as is NGC 7114 and probably NGC 6847.

The very large and loose open clusters found by the Herschels (NGC 6832, 6874, 6895, 6997, 7024, 7058, 7093, and 7175) may or may not be real. The visual impression created by extended clusters is very much affected by the aperture of the telescope and the size of the field of view. Large clusters, for example, can often be seen only at very low powers. Also, the precise meaning of the word "cluster" is unclear. In the dense heart of the Milky Way, the star fields are so rich that patterns of random background stars will often give the impression of a cluster or grouping.

The remaining five objects consist of one double star, a probably small cluster by d'Arrest, and three mysteries.

20 'Nonexistent' Objects

NGC	RA (2000.0)	Dec	Observers	Original Description
6832	$19^h\ 48.2^m$	59° 25′	JH	A very large cluster (about 50′), little condensed, with stars from 7^m...
6847	$19^h\ 57.0^m$	29° 20′	WH	Faint round nebula.
6856	$19^h\ 59.3^m$	56° 07′	JH	A pretty small cluster (about 3′), pretty much condensed and irregularly round, with stars 12^m...16^m
6874	$20^h\ 07.8^m$	38° 14′	WH, JH	A coarsely scattered cluster of stars, poor pretty rich but little condensed.
6895	$20^h\ 16.5^m$	50°13	WH	A coarsely scattered cluster of stars, pretty rich but little condensed.
6896	$20^h\ 18.1^m$	30° 38′	d'Arrest	A small (about 2′) cluster, stars very small (faint?) and possible nebulosity.
6989	$20^h\ 54.1^m$	45° 16′	WH	A coarsely scattered cluster, considerably large (about 18′) but with pretty small (faint?) stars.
6997	$20^h\ 56.5^m$	44° 38′	WH	A coarsely scattered cluster, poor and little condensed, with large (bright?) stars.
7011	$21^h\ 01.9^m$	47° 19′	JH	Cluster
7024	$21^h\ 06.0^m$	41° 29′	WH, JH	A coarsely scattered cluster, poor and little condensed, with stars from 10^m...
7037	$21^h\ 10.8^m$	33° 43′	JH	A pretty rich cluster but faint and irregular, with stars from 11^m...15^m
7050	$21^h\ 15.2^m$	36° 11′	JH	Cluster
7054	$21^h\ 20.7^m$	39° 10′	Stephan	A very faint and very small nebula (10′ to 20′), round and with a faint star involved.
7058	$21^h\ 21.0^m$	50° 48′	JH	Cluster, poor and little condensed.
7071	$21^h\ 26.5^m$	47° 56′	JH	A small (about 2′) compressed cluster, considerably elongated in shape.
7093	$21^h\ 34.3^m$	46° 00′	JH	Cluster, poor and little condensed.
7114	$21^h\ 41.7^m$	42° 50′	...	Nebulous variable star, possibly a planetary nebula.
7143	$21^h\ 48.9^m$	29° 57′	JH	Very faint, possibly a double star and possibly enveloped in nebulosity. Dreyer notes that John Herschel's original sighting was checked by other observers, with the following results: 'No nebulosity seen at Birr Castle in 6 observations. Probably only a vF D °."
7150	$21^h\ 50.4^m$	49° 45′	Bond	Nebula
7175	$21^h\ 58.8^m$	54° 49′	JH	A very large (about 50′) cluster, pretty rich but little condensed.

photographs, yet are difficult visually. Only the small patch known as **NGC 6979** is "routine" for large telescopes. At discovery, Herschel catalogued it among his class II (faint nebulae).

Most amateurs know of the **North America Nebula**, yet relatively few have actually seen it. Due to its vast expanse (120′ x 100′), the nebula is difficult to distinguish against its rich background. At Stellafane in Springfield, Vermont, I have always found NGC 7000 difficult in my 4¼-inch RFT. It is much easier in 7x50 binoculars and even with the naked eye. Indeed, if you know what to look for, the North America Nebula is most easily seen without any optical aid at all! A hint for spotting this celestial continent is to look first for "Mexico," "Florida," and the "Gulf of Mexico." This area offers the greatest contrast, due to dark nebulosity immediately to the west. The distance to NGC 7000 is about 1600 light-years. Superimposed on NGC 7000 is the unspectacular open cluster **NGC 6997** — a loose collection of about 25 stars of magnitude 11 and fainter.

Out in the "Atlantic" is the **Pelican Nebula**, IC 5067/70. The brightest section, IC 5067, is viewed best with a wide-field eyepiece under very dark clear skies. Using averted vision, my 8-inch showed about 20′ of the Pelican's "neck" against a multitude of stars. Switching to shorter focal length eyepieces only caused the faint glow to disappear. For those who have tried in vain to see it, a good rule of thumb is set by NGC 7000. If you can spot the North America Nebula naked-eye, then the night's clear enough to try for the Pelican.

If you think the North America Nebula is easy, and the Pelican a snap, just try **IC 5076**! A large scope, clear skies, a superior eyepiece, and something of a vivid imagination are all prerequisites for this one. Search for a soft glow surrounding a 6th magnitude star, lying one Moon diameter west of 59 Cygni. If you spot it, be sure to let us know.

Have you ever seen a black hole? Of course not, no one has! However, many candidates are suspected, due to their strong X-ray emission. One of the strongest X-ray sources is designated **Cygnus X-1**. Studies indicate that its position is nearly identical to that of the ninth magnitude star **HDE 226868** (also known as **BD +34° 3815**). This star is classified as a blue supergiant (spectral class B0 Ib) and is about 15 times more massive than the Sun. Its spectrum displays a variable radial velocity with a period of just over 5.5 days, indicating the orbital period of the invisible companion. Further calculations show this companion weighs about 8 solar masses. As a result, Cygnus X-1 is the most convincing case for the existence of a black hole.

While you can't see Cygnus X-1 itself visually, its companion star *can* be seen in even a 2-inch telescope. Look less than half a degree northeast of Eta Cygni. (An excellent finder chart is published on page 795 in volume 2 of *Burnham's Celestial Handbook*.)

NGC 7027 is a curious object. T.W. Webb is credited with its discovery, on November 14, 1879. He described it as a planetary nebula of magnitude 8.5, as does Burnham. However, recent observations indicate it contains highly ionized atoms, suggesting it is an emission nebula. It measures only about 5″ across, proving a difficult target in all but the largest amateur scopes. Some observers see not one, but two nebulae, seemingly in contact. The *Deep Sky Observer's Handbook*, volume 2, shows a view through the 98-inch, then at the Royal Greenwich Observatory, which strongly resembles the Whirlpool Galaxy (M51) in Canes Venatici.

About 3° north of 63 Cygni are three reflection nebulae, positioned just south of a 6th magnitude star. These are plotted, unlabeled, in the *Sky Atlas 2000*. A moderate size telescope reveals a dim glow in this region.

NGC 7044 is a small, dense open cluster which has received little recognition among amateurs. Neither the Webb Society's nor Burnham's handbooks make any mention of it at all. This is unfortunate, as it is a fine object and many observers are probably passing it by. My 8-inch reflector showed about 20 stars of magnitude 12 and fainter, giving an overall magnitude of 11. All were packed into a 7′ area that resembles an arrowhead in shape. Now that you know about NGC 7044, go out and add it to your deep sky conquests. You'll find it about 3° southeast of Xi (ξ) Cygni.

Of all the planetaries in Cygnus, **NGC 7008** has the largest apparent diameter, measuring 86″ x 69″. But keep in mind that sheer size is not always beneficial to the observer. NGC 7008's light is equal to an 11th magnitude star, but when this is spread over a minute of arc, low surface brightness results. Unless you scan very slowly, you might pass right over it. Once you capture it, switch to a moderate power for a better view. Its major axis runs north-south, with two faint stars superimposed on the north edge. Neither of these is the actual central star, which, despite being rated 13th magnitude, remained invisible in my 8-inch.

A fairly easy planetary is **NGC 7026**, though it would be far more difficult to find were it not for its proximity to 63 Cygni. Views through telescopes as small as 3-inch apertures indicate this to be shaped like a stubby cigar, glowing with a pale green tinge. Large telescope users may catch fleeting glimpses of the 15th magnitude central star.

Like NGC 7008, **NGC 7048** suffers

Sketch by Alan Goldstein

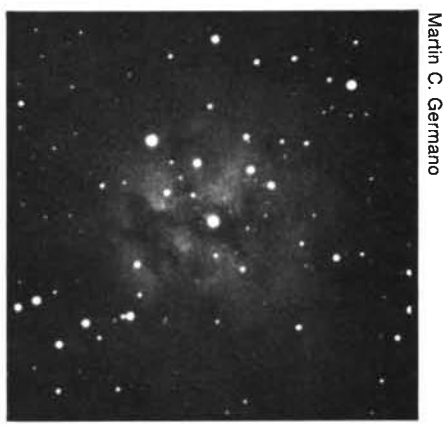
NGC 6910 4-inch f/15 refractor 172x

Tom Dessert

M39 4-inch f/10 Newtonian 15 min., 103a-F

Sketch by Chris Quinnert

NGC 6946 8-inch f/10 SCT 50X



Martin C. Germano

IC 5146 8-inch f/10 SCT 90 min., 103a-F

Deep Sky Objects in Cygnus

Type	Object	M#	R.A.(2000)Dec.	Mag.	SB	Mag.*	N*	Size	Sep./Per.	P.A.	Dist.	Lin.Diam.
★²	Beta (β)	—	19h30.7m +27°57′	3.1,5.1	—	—	—	—	34.3″	54°(59)	120pc	4400 AU
LPV	R	—	19h36.8m +50°12′	6.6↔14.1	—	—	—	—	426d	—	—	—
⊙	NGC 6811	—	19h38.3m +46°34′	6.8	—	10...	249	20.0′	—	—	—	—
⊙	NGC 6819	—	19h41.3m +40°13′	7.3	—	11...	929	9.5′	—	—	—	—
LPV	RT	—	19h44.0m +48°46′	7.3↔11.8	—	—	—	—	190d	—	—	—
■	NGC 6826	—	19h44.9m +50°31′	8.7	—	10.6	—	27″x24″	—	—	—	—
★²	Delta (δ)	—	19h44.9m +45°07′	3.0,6.5	—	—	—	—	2.2″	247°(61)	80pc	220 AU
■	NGC 6833	—	19h49.7m +48+58′	12.0	—	20.3	—	2″	—	—	—	—
LPV	Chi (χ)	—	19h50.5m +32°55′	5.1↔14.3	—	—	—	—	407d	—	100pc	—
⊙	NGC 6834	—	19h53.2m +29°29′	7.8	—	10...	12.8	5.5′	—	—	—	—
BH	Cygnus X–1	—	19h58.4m +35°12′	—	—	—	—	—	—	—	2.5kpc	—
■	NGC 6857	—	20h01.8m +33°31′	11.4	—	13.3	—	40″	—	—	—	—
⊙	NGC 6866	—	20h03.7m +44°00′	7.6	—	10...	129	8.0′	—	—	—	—
⊙	NGC 6871	—	20h06.7m +35°51′	5.2	—	7...	66	40.0′	—	—	—	—
⊙	NGC 6874	—	20h08.7m +38°19′	—	—	—	—	7.0′	—	—	—	—
■	NGC 6884	—	20h10.4m +46°28′	12.6	—	18.6	—	6″	—	—	—	—
■	NGC 6881	—	20h10.8m +37°25′	14.3	—	—	—	5″	—	—	—	—
⊙	IC 1311	—	20h10.9m +41°11′	13.0	—	17...	30	5.0′	—	—	—	—
⊙	NGC 6883	—	20h12.2m +35°55′	8.3	—	10...	30	11.5′	—	—	—	—
SNR	NGC 6888	—	20h12.5m +38°25′	11	14	—	—	20.0′x10.0′	—	—	—	—
■	NGC 6894	—	20h16.4m +30°34′	11.5p	—	17.5p	—	55″	—	—	—	—
□E	IC 1318	—	20h16.5m +41°48′	—	—	2.3	—	24.0′x17.0′	—	—	—	—
⊙	IC 4996	—	20h17.3m +37°42′	7.3	—	9...	56	5.6′	—	—	—	—
□E	IC 1318	—	20h18.8m +40°39′	—	—	2.3	—	50.0′x25.0′	—	—	—	—
⊙	NGC 6896	—	20h19.0m +30°43′	—	—	—	—	—	—	—	—	—
⊙	Collinder 419	—	20h19.0m +40°47′	5.4	—	—	—	4.0′	—	—	—	—
□E	IC 1318	—	20h19.8m +40°07′	—	—	2.3	—	45.0′x25.0′	—	—	—	—
⊙	Dolidze 5	—	20h20.5m +39°23′	—	—	—	30	10.0′	—	—	—	—
⊙	NGC 6910	—	20h23.1m +40°47′	7.4	—	10...	66	8.0′	—	—	—	—
□E	IC 1318	—	20h23.8m +40°45′	—	—	2.3	—	85.0′x50.0′	—	—	—	—
⊙	NGC 6913	M29	20h24.0m +38°31′	6.6	—	9...	81	7.0′	—	—	—	—
⊙	Collinder 421	—	20h24.1m +41°47′	10.0	—	—	22	6.0′	—	—	—	—
□E	NGC 6914	—	20h25.1m +42°20′	10	12	9.0	—	6.0′	—	—	—	—
□E	IC 1318	—	20h28.5m +39°57′	—	—	2.3	—	70.0′x20.0′	—	—	—	—
⊙	NGC 6939	—	20h31.9m +60°43′	7.8	—	12...	301	8.0′	—	—	—	—
§Sc	NGC 6946	—	20h34.9m +60°08′	9.7	—	—	—	9.0′x7.5′	—	—	5Mpc	—
	[across border in Cepheus]											
SNR	NGC 6960	—	20h45.6m +30°43′	7	12	—	—	70.0′x6.0′	—	—	450pc	10pc
□E	IC 5067–70	—	20h48.6m +44°22′	9	14	9	—	80.0′	—	—	500pc	—
SNR	NGC 6979	—	20h51.5m +31°01′	11	14	—	—	—	—	—	—	—
□R	IC 5076	—	20h55.8m +47°25′	10	15	6.0	—	7.0′	—	—	—	—
SNR	NGC 6992–5	—	20h56.4m +31°42′	7	12	—	—	78.0′x8.0′	—	—	450pc	10pc
⊙	NGC 6997	—	20h56.7m +44°39′	10.0	—	11...	40	8.0′	—	—	500pc	1pc
□E	NGC 7000	—	20h58.7m +44°20′	4.5	13	9	—	120.0′x100.0′	—	—	500pc	15pc
■	NGC 7008	—	21h00.6m +54°33′	13.3p	—	13.3	—	86″x69″	—	—	—	—
⊙	Collinder 428	—	21h03.2m +44°35′	8.7	—	—	20	10.0′	—	—	450pc	—
★²	61	—	21h06.3m +38°40′	5.3,5.9	—	—	—	—	28.4″	144°(68)	3.4pc	84 AU
■	NGC 7026	—	21h06.3m +47°51′	11.8p	—	14.2	—	28″x13″	—	—	—	—
CCV	SS	—	21h06.6m +43°33′	8.2↔12.0	—	—	—	—	Irr	—	30pc	—
□E	NGC 7027	—	21h07.1m +42°14′	10.4p	—	—	—	18″x11″	—	—	—	—
⊙	NGC 7044	—	21h13.9m +42°35′	12.0	—	15...	60	7.0′	—	—	—	—
■	NGC 7048	—	21h14.2m +46°16′	11.3p	—	18.0p	—	60″x50″	—	—	—	—
⊙	NGC 7062	—	21h23.3m +46°23′	8.3	—	10...	85	5.0′	—	—	—	—
⊙	NGC 7063	—	21h25.4m +36°36′	7.0	—	9...	66	12.0′	—	—	—	—
⊙	NGC 7071	—	21h27.4m +48°02′	10.0	—	—	—	4.0′	—	—	—	—
⊙	NGC 7082	—	21h27.4m +48°02′	7.2	—	10...	182	14.0′	—	—	—	—
⊙	NGC 7086	—	21h28.7m +47°03′	8.4	—	10...	80	25.0′	—	—	—	—
⊙	NGC 7092	M39	21h32.2m +48°26′	4.6	—	7...	28	30.0′	—	—	245pc	2.2pc
■	IC 5117	—	21h32.5m +50°57′	13.3	—	—	—	2″	—	—	—	—
■	Humason 2-1	—	21h33.1m +39°38′	12.7	—	—	—	5″	—	—	—	—
⊙	NGC 7127	—	21h43.8m +53°38′	10.0	—	—	10	2.0′	—	—	—	—
⊙	NGC 7128	—	21h44.1m +53°43′	9.7	—	11...	71	2.0′	—	—	—	—
□R	IC 5146	—	21h53.3m +47°16′	9	14	10.0	—	10.0′x10.0′	—	—	—	—

Column 1 = type code: ★² =double star; LPV =long period variable; CCV = cataclysmic variable; ⊙ = open star cluster; □E = emission nebula; □R = reflection nebula; ■ = planetary nebula; SNR = supernova remnant; BH = possible black hole site; Sc = Sc-type spiral galaxy. **Column 2** = name in *Revised New General Catalogue* by J. Sulentic and W. Tifft, and additional lists. **Column 3** = number in Messier catalogue, if applicable. **Column 4** = coordinates for epoch 2000.0. **Column 5** = integrated magnitude in V (visual) or P (photographic) system. **Column 6** = mean surface brightness for nebular objects in magnitudes per square arcminute. **Column 7** =magnitude of central illuminating star or brightest cluster members. **Column 8** =number of stars in cluster. **Column 9** =angular size in arcminutes or arcseconds. **Column 10** = separation in arcseconds or period in days. **Column 11** =position angle in degrees with year measured in parentheses. **Column 12** = distance in parsecs. **Column 13** =linear diameter in parsecs or distance between stars in Astronomical Units. Data for open clusters from *Catalogue of Open Cluster Data*, 3rd edition, by G. Lynga, and Brian Skiff, from photometric work at Lowell Observatory. Data for galaxies from G. de Vaucouleurs, A. de Vaucouleurs, and H. Corwin, *Second Reference Catalogue of Bright Galaxies*. Estimated high-end mean surface brightnesses by D. Eicher and B. Skiff. Special thanks to Brian Skiff for meticulously collecting data.

from low surface brightness. It is equivalent to an 11th magnitude star, but is 60″ in diameter. Nonetheless, it is faintly visible in a 6-inch, but with little detail. Two other difficult planetaries are **IC 5117** and **Hu 1-2**. Each appears stellar, and will require your scope's highest available power for positive identification. Even then it is difficult to tell them apart from the myriad of field stars.

Far more impressive, especially for small telescope owners, is Messier's other Cygnus object, **M39**. This is a bright, loose open cluster located about 10° northeast of Deneb, and is visible to the naked eye. Its ideal viewing instrument is either a finder scope or binoculars. As you increase aperture and magnification, the splendor of the cluster decreases. My 4¼-inch RFT reveals about two dozen suns brighter than magnitude 10.5 arranged in a triangular shape. Some observers note a three-dimensional effect between the cluster and the fainter field stars.

South of M39 is a trio of open clusters. **NGC 7062** is small but fairly rich, with about two dozen stars spread over a 5′ area. Most members are magnitude 11 and 12 which may blend into a nebulous glow in smaller telescopes. A far sparser cluster is **NGC 7071**, which is unplotted in the *Sky Atlas 2000*. It is a difficult object to make out, as its brightest stars are only magnitude 12. The apparent diameter of 7071 is about equal to 7062. The third of these clusters, **NGC 7082**, is larger than either of its celestial neighbors. Here you will discover many stars of magnitudes 10 through 13, spread over 25′.

Just south of 69 Cygni is a little-known open cluster, **NGC 7063**, that is not plotted on most star atlases, yet which contains some two dozen stellar members. My notes recall a bright object, whose stars range in brightness from 9th to 12th magnitude, scattered in a "bow tie" shape.

Astronomical history was made in 1838, when German astronomer Friedrich Bessel determined the first accurate parallax of a star. Bessel observed that the double star **61 Cygni** exhibited a parallax of 0.3″. Using simple trigonometry, he then computed the star to be 10.3 light-years from Earth. This compares closely to the presently-accepted value of 11.2 light-years. 61 Cygni is a beautiful sight in even a 2-inch telescope. The binary system is made up of two brilliant orange K-type stars. Their separation of 29″ corresponds to a true gap of nearly 10 billion miles.

One of the most fascinating variable stars to watch and follow is **SS Cygni**. Classified as a cataclysmic variable of the U Geminorum class, this star normally leads a placid existence, shining at an unimpressive 12th magnitude. At irregular intervals, however, it will brighten dramatically. Within 24 to 72 hours, SS Cygni will become 40 times more luminous and will reach 8th magnitude. It may then remain at maximum for 8 to 18 days before fading.

Based on spectroscopic observations, astronomers now know that SS Cygni is a binary star. One component is a yellow dwarf, the other a blue dwarf. The period is a scant 6.5 hours, and probably less than 100,000 miles probably separates the two. The bluish star is thought to be responsible for the spectacular outbursts.

Now scan 3° north of M39 to encounter **NGC 7086**. A 6-inch reflector discloses a rich but faint gathering of many stars immersed in a soft glow, suggesting many fainter stars. It measures about 25′ in diameter and offers a nice sight in medium size telescopes.

Still farther north is a pair of small clusters. **NGC 7127** is about 3′ across and quite faint. My 8-inch was able to resolve only a half a dozen stars against the nebulous glow of other members, too faint to detect individually. Equally difficult is nearby **NGC 7128**. Again, the 8-incher revealed about six 12th magnitude suns clustered into a 3′ field. While they are unimpressive to most neophytes, the veteran deep-sky observer will gladly add them to his "you-call-this-thing-a-cluster?" list.

A decade ago, most backyard observers would have classed IC 5146 (popularly known as the **Cocoon Nebula**) as one of those nebulae detectable only in photographs. But with the recent advent of large-aperture amateur telescopes and nebular filters, the Cocoon has progressed from the impossible to the merely difficult. From Long Island, Warren Hamburger has seen it as a faint amorphous glow using his 10-inch f/5.6 reflector. It has many dark lanes (much like the Trifid Nebula in Sagittarius) but these are difficult to observe visually. Perhaps a large telescope will provide its owner with a glimpse.

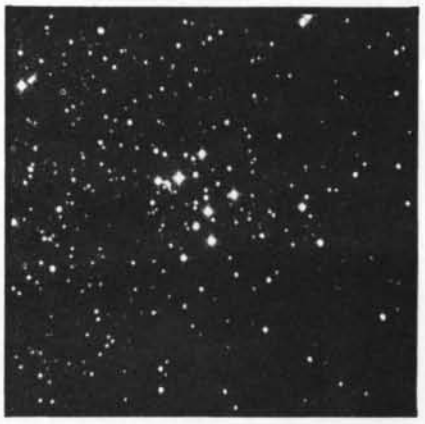
* * *

Within Cygnus lie many challenging targets for the deep-sky hunter. Be sure to record all you find when you observe these objects — and while you are at it, why not send a copy along to DSM? Your reports are always welcome. But if it's cloudy, or if there's a bright Moon washing out the sky, don't panic. Cygnus will remain high in the sky long after the standard summer constellations are lost in evening twilight, beckoning us to enjoy summertime's swan song.

Phil Harrington is an active observer who lives in New York. He is a frequent contributor to DSM; his last article was published in DSM #5.

Sketch by Matt Penn

NGC 6826 6-inch f/8 Newtonian 100x

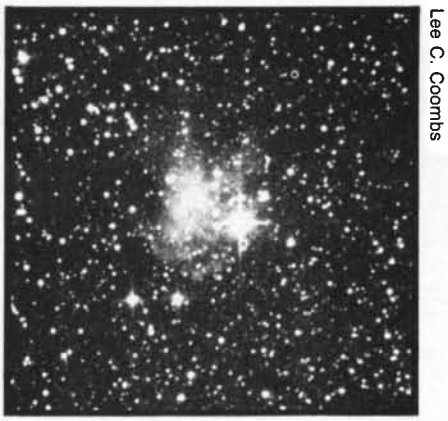


Jack Newton

M29 12.5-inch f/4.5 Newtonian 13 min., 103a-F

Sketch by Alan Goldstein

NGC 7027 4-inch f/15 refractor 186x

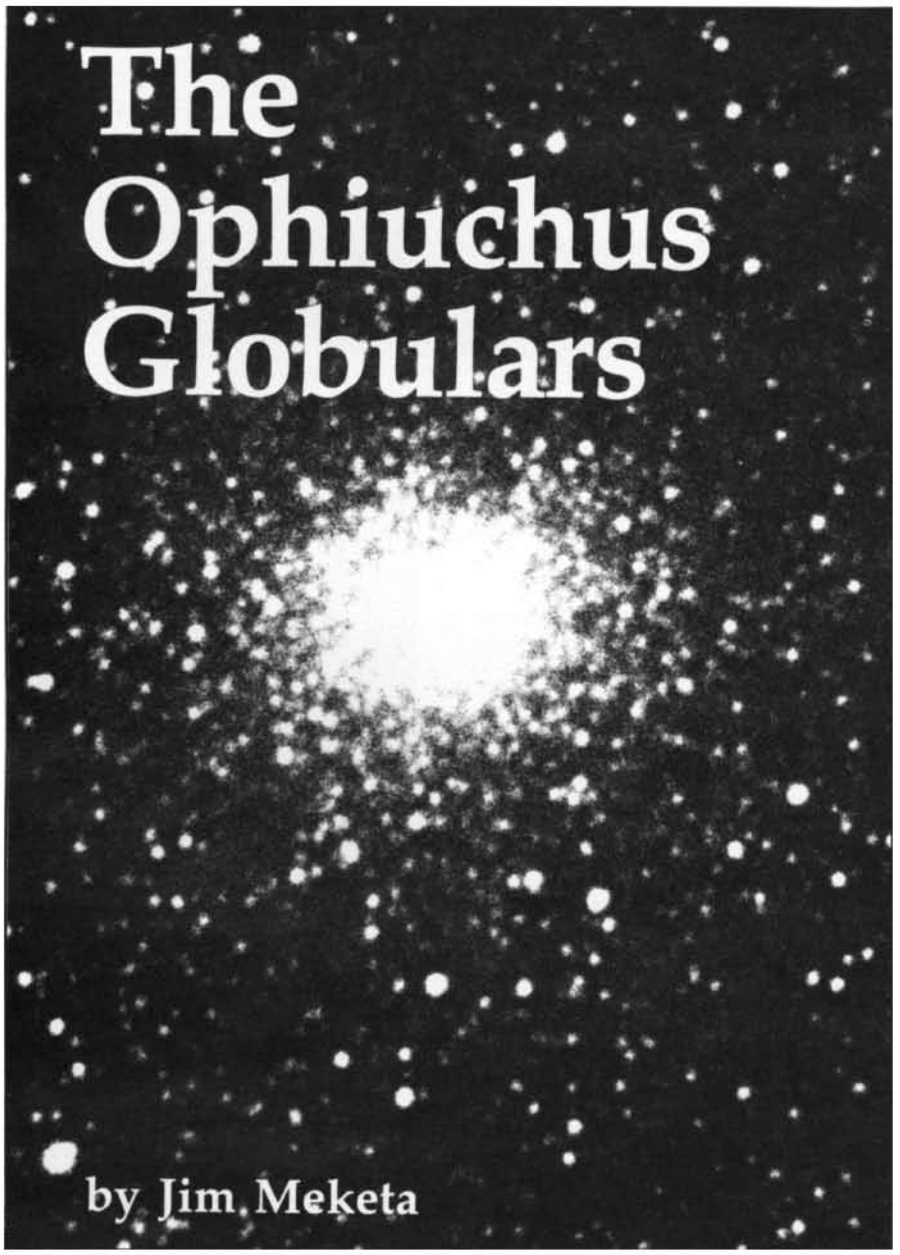


Lee C. Coombs

IC 5076 10-inch f/5 Newtonian 10 min., 103a-O

The Ophiuchus Globulars

by Jim Meketa



Above: M19 — the most elliptical globular cluster? Photo by Martin Germano.

Ophiuchus is not outstanding to the naked eye — yet this stellar realm contains a fifth of all the globular clusters in the sky!

For those of us who live in the northern hemisphere, the shortest nights of the year fall in June. At mid-month, for example, evening twilight at the latitude of Boston (42°) ends at 10:15 p.m. and morning twilight begins at 1:50 a.m. This leaves an astronomically-dark sky for only 3½ hours. As the evening light fades, the great galaxy clouds in Coma and Virgo are setting in the west, while the eastern horizon is filled with the rising summer Milky Way. And high in the southern sky, ideally situated for viewing throughout the brief night, lies Ophiuchus the Serpent Bearer. Bracketed by the head of the serpent (Serpens Caput) and his tail (Serpens Cauda), Ophiuchus fills most of the sky between Antares and Vega.

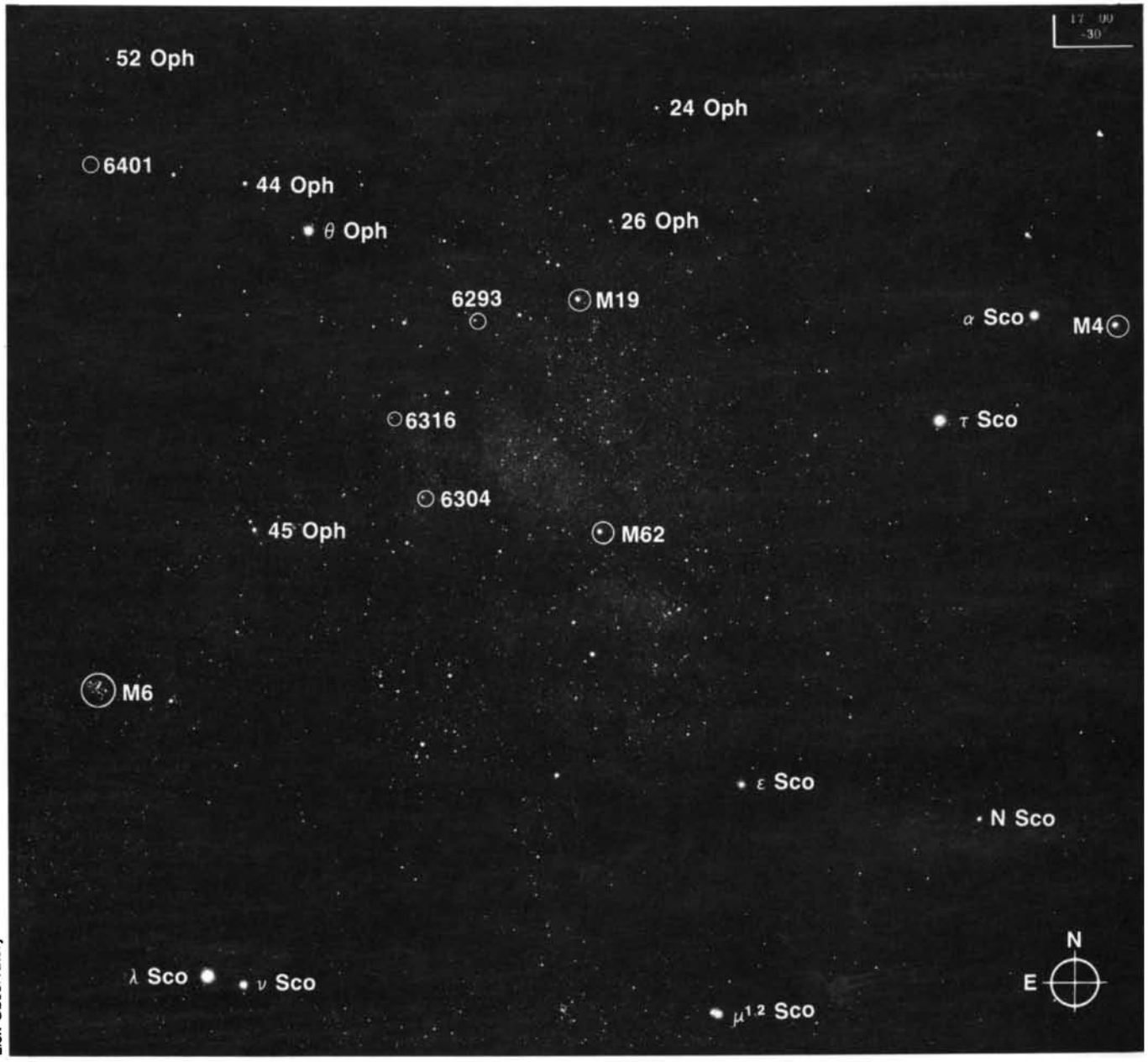
In Ophiuchus we are looking toward where the northwestern side of our Galaxy's central bulge merges into the disk. Most of this area is filled with residual gas and dust, and countless Population II stars like our Sun. It is not surprising then that Ophiuchus is nearly devoid of galaxies — their feeble light simply cannot punch through all the intervening material.

Globular clusters are another matter, however. They are bright, compact, and relatively nearby — and their high intrinsic luminosity makes them some of the most prominent deep-sky objects in our Galaxy, despite the fact that most lie in heavily-obscured regions of sky. In "global" terms, these clusters form a roughly spherical shell around the central part of the Galaxy. In the first decades of this century, Harlow Shapley noted that nearly all the globulars are found in one region of sky — and from this deduced that the Sun was not at the Galaxy's center. Though it is not as rich in them as Sagittarius, Ophiuchus abounds with globular clusters — 20 can be seen in visible wavelengths and at least five more are so reddened by dust that they are visible only in the infrared. Thus this single constellation contains fully one-fifth of all known galactic globular clusters, making it a wonderful hunting ground for those of us who enjoy these strange and beautiful objects.

A good starting place is with **M10** (NGC 6254) and **M12** (NGC 6218). You can find them easily in binoculars as two fuzzy patches just 3.4° apart on the western boundary of the constellation. They shine with about the same luminosity, but M10 is easier to locate because it lies just 1° east of 30 Ophiuchi, a 5th magnitude red star visible to the naked eye. Various references cite M10's magnitude between 6.7 and 7.3, and the spread for M12 is even greater, 6.6 to 7.6. To me both appear to be just below the visual threshold, about magnitude 6.7, and M10 seems a shade more obvious.

On long exposure photos M10 shows a diameter just over 12 arcminutes, but in amateur telescopes the faint outlying stars are invisible and the cluster appears much smaller. Under very dark skies at Fort Davis, Texas, I used my 18-inch Newtonian on M10 and estimated its diameter at about 6′. At 129x, the moderately condensed core appeared to be about 3″ in diameter, and resolved into many bright stars. Since M10 contains at least 20 stars between magnitudes 11.5 and 13, telescopes as small as 6-inches' aperture can achieve some resolution. (My 4.25-inch finder at 16x couldn't do it, however). Actually, the loose structure of M10 — it is of Shapley class VII — makes resolution easier, as the brightest core stars are more separated and distinct.

While M10 is certainly one of the brightest and most beautiful clusters in



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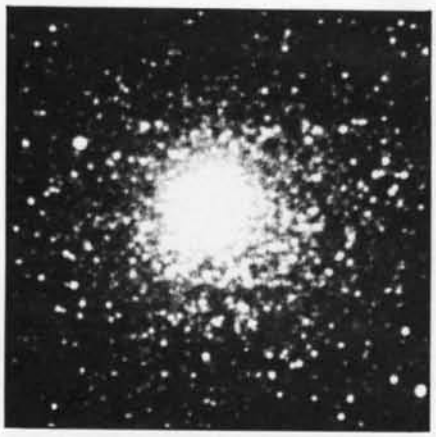
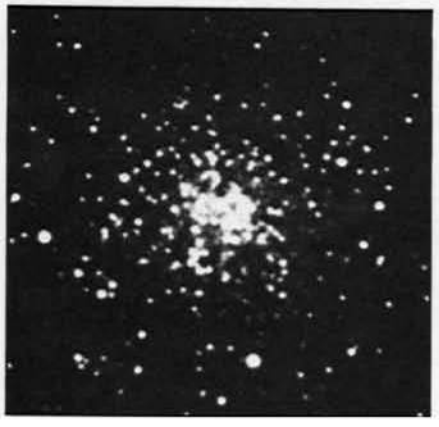
the northern sky, my favorite of the pair is M12. Although it contains only eight stars brighter than 13th magnitude, its loose structure (class IX) often gives an impression of resolution in small instruments. In a large telescope, M12 is a magnificant globular, with a semi-condensed core about 3″ in diameter surrounded by radiating streams of stars. To my eye, these streamers make M12 look like a large scintillating pinwheel, a spiral appearance first noted by Lord Rosse. The unusual beauty of this cluster is further enhanced by a rich Milky Way background and a single bright red field star set on the cluster's southern edge.

Charles Messier discovered M10 on the night of May 29, 1764, and located M12 the following night. Ten years later Johannes Bode rediscovered them. Both observers saw the clusters as nebulous, unresolved objects, though Messier contiued to examine M10 over the years with various telescopes, making notes on its appearance in 1769, 1780, and 1781. Obviously Messier saw only the highly-condensed core in his early refractors, since he measured M10 as 4′ across, and M12 as only 3′. William Herschel was the first to realize the true nature of these clusters — a tribute to the quality of his large hand-made reflectors. In 1783 Herschel exmained M12, for example, and immediately resolved it into "a brilliant cluster 7′ or 8′ in diameter — the most compressed parts about 2′." Herschel's description seems to fit exactly the view you get today with a 6-inch or 8-inch telescope.

As you examine M10 and M12, remember that the stars you see winking faintly across the face of these clusters are among the most luminous stars in our Galaxy. Their spectra show them to be nearly pure hydrogen and helium, evidence they formed long ago when the Galaxy was young and as yet uncontaminated with heavier elements. Over the billions of years that have passed since their birth, these stars have evolved away from the main sequence to become red giants. Some are evolving through a temporary period of instability; these are the Cepheid and RR Lyrae variables that provide the best clue to the distance and size of the clusters.

Much of the beauty and grandeur we sense in these clusters derives from their appearance as incredibly compact swarms of stars, with thousands of tiny pinpricks of light nearly in contact. This impression of great stellar density, however, is an illusion, as Robert Burnham, Jr. points, out in his description of M13 in Hercules. His model of a large globular cluster





Top: M62 — almost in the clutches of the Scorpion. Photo by Martin Germano. Middle: M9 — nearest to the core of the Galaxy? Photo by Tom Dessert. Bottom: M107 — strangely sparse and loose. Photo by Martin Germano.

The Ophiuchus Globulars

Object	M#	R.A.(2000)Dec.	Mag.	Size	CC	Dkpc	Dpc	V
NGC 6171	M107	16h32.5m −13°03′	8.2	10.0′	X	6.7	19	23
NGC 6218	M12	16h47.2m −01°57′	6.9	14.5′	IX	5.9	25	1
NGC 6254	M10	16h57.1m −04°07′	6.6	15.1′	VII	4.4	19	4
NGC 6266	M62	17h02.2m −30°07′	6.5	14.1′	IV	6.0	25	89
NGC 6273	M19	17h02.6m −26°15′	6.8	13.5′	VIII	10.1	40	4
NGC 6284		17h04.6m −24°45′	9.0	5.6′	IX	11.4	19	6
NGC 6293		17h11.1m −26°34′	8.4	7.9′	IV	8.9	20	5
NGC 6304		17h14.6m −29°27′	8.4	6.8′	VI	4.8	9	21
NGC 6316		17h16.6m −28°08′	9.0	4.9′	III	13.7	20	61
NGC 6325		17h18.0m −23°45′	10.7	4.3′	IV	4.0	5	0
NGC 6333	M9	17h19.1m −18°31′	7.8	9.3′	VIII	9.1	25	12
NGC 6342		17h21.1m −19°35′	10.1	3.0′	IV	9.8	9	0
NGC 6356		17h23.7m −17°49′	8.3	7.2′	II	18.0	38	10
NGC 6355		17h24.0m −26°22′	9.8	5.0′	——	5.6	8	0
NGC 6366		17h28.7m −05°04′	10.1	8.3′	XI	8.5	21	2
NGC 6402	M14	17h37.6m −03°17′	7.5	11.7′	VIII	13.8	47	85
NGC 6401		17h38.7m −23°55′	9.4	5.6′	——	8.5	14	3
NGC 6426		17h44.9m +03°11′	11.5	3.2′	IX	17.4	16	12
NGC 6517		18h02.7m −08°57′	10.3	4.3′	IV	7.0	9	0

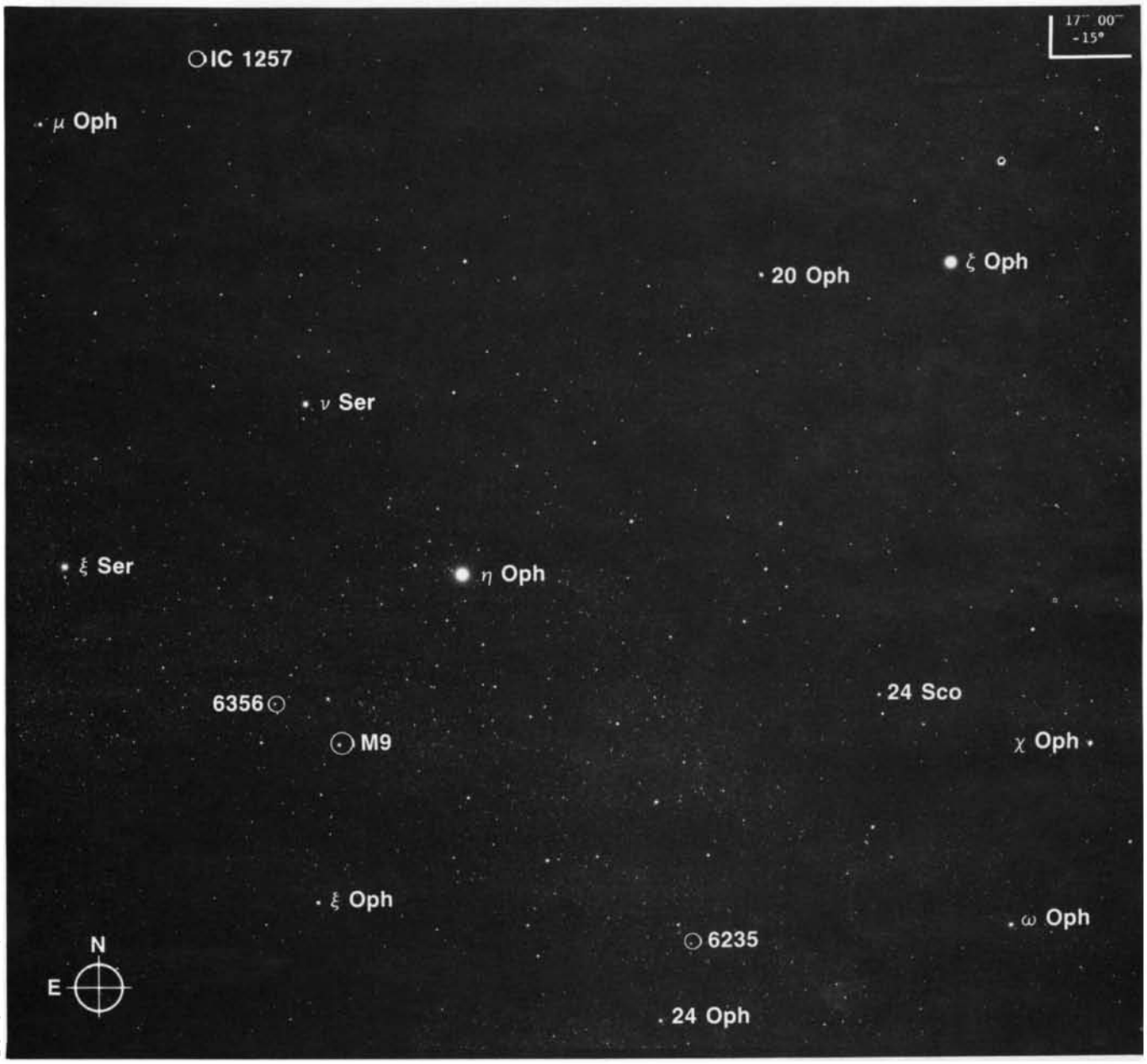
Column 1 = name in *Revised New General Catalogue*. **Column 2** = Messier catalogue number if applicable. **Column 3** = coordinates for epoch 2000.0. **Column 4** = integrated magnitude in V (visual) light. **Column 5** = angular diameter in arcminutes. **Column 6** = Shapley concentration class: I largest, XII smallest concentration. **Column 7** = distance from Sun in kiloparsecs. **Column 8** = linear diameter in parsecs. **Column 9** = number of known variable stars. Data from G. Alcaino, *PASP* **89**:491, 1977, and Racine and Harris, *ApJ* **196**:413, 1975.

represents each star by a grain of sand 0.03 inches in diameter. For a globular like M13, the average grains of sand (stars) would be separated from each other by *three miles*, with a million grains filling a sphere 300 miles in diameter! Even in the core, individual grains would be thousands of feet apart. At a distance of 6.2 kpc (20,200 light-years), M10 is slightly closer than M12, which resides about 7.4 kpc (24,100 ly) away. Thus, as Burnham notes, each cluster must appear as a beautiful 2nd magnitude object in the other's sky.

Another fine Messier globular lies 10° due east of M10 — **M14** (NGC 6402). An easy object in a 4.25-inch f/4 finder at 16x, in larger telescopes M14 resembles a small, round version of Omega Centauri. The cluster is considerably more remote than either M10 or M12 — perhaps 14.5 kpc (47,300 ly) — and is more heavily obscured by galactic dust. Consequently, its 25 brightest stars average magnitude 15.7 (as opposed to 14.2 for M10 and 14.1 for M12). This means you'll need a telescope at least 12 inches in aperture for any trace of resolution. Steve Gottlieb, using averted vision and viewing M14 with a 13.1-inch telescope in the California Sierras, reported that he could see about a dozen faint stars in the outer halo. In my 18-inch the cluster is well resolved into uniform stars, with only a slight condensation toward the middle. This cluster is loose but contains many stars, giving the appearance of a small area evenly sprinkled with a dense profusion of very faint stardust. It makes a magnificent contrast with the M10 and M12 pair.

If you now turn 3° southwest to the 5th magnitude star 47 Ophiuchi, you will find fainter globular cluster **NGC 6366** just east of the star. While this 12th magnitude object could not have been detected with Messier's small instruments, it was surprisingly passed over by the Herschels, who studied this region carefully with 12-inch and larger telescopes. NGC 6366 is a round milky patch of faint light, perhaps 6′ across, with indistinct edges. The cluster shows virtually no central condensation (Shapley class XI), which reduces its mean surface brightness and makes it hard to observe in telescopes with longer focal lengths. (This may explain why the Herschels skipped over it — their telescopes had long focal ratios.) At Fort Davis I saw many very faint stars, indicating at least partial resolution with the 18-inch aperture. Steve Gottlieb also reports 12 or 15 faint stars in his 13.1-inch scope, but no resolution in his 8-inch f/10 SCT.

Exactly 2° south of NGC 6366 lies **IC 1257**, an unusual object that may or may not be a globular cluster. If it is a globular it must be extremely remote to



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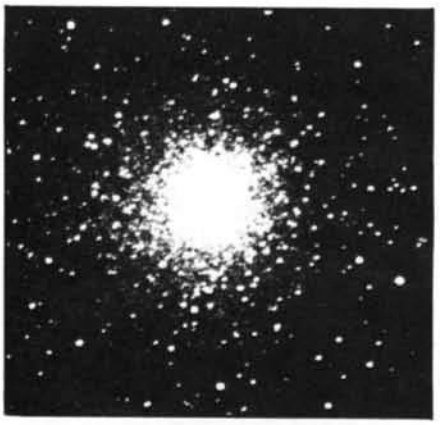
account for its apparent small size and underluminosity. In my 18-inch it shows only under excellent conditions and then as a threshold object about 1″ in diameter. There is no trace of resolution or detail and even the size and shape are indistinct. Observers with large telescopes and dark skies may have better luck with this elusive cluster.

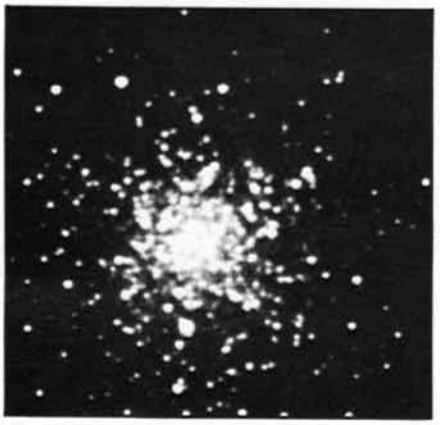
There is only one globular north of the celestial equator in Ophiuchus. **NGC 6426** lies just 1.5° due south of Cheleb (Beta [β] Ophiuchi), and having a 2nd magnitude star nearby is fortunate, for otherwise this heavily-obscured globular would be difficult to find! Using Cheleb as a reference, it is possible to detect NGC 6426 with as little as a 3-inch scope, since its integrated magnitude is about 11.5. But even in my 18-inch reflector, NGC 6426 is no more than an extremely faint, tenuous patch of light about 2′ in diameter. I have seen a few dim stars winking in and out, but there is no real resolution even under the best conditions. (After you have located NGC 6426, try for two other nearby objects: Barnard's Star and the large, sparse open cluster IC 4665.)

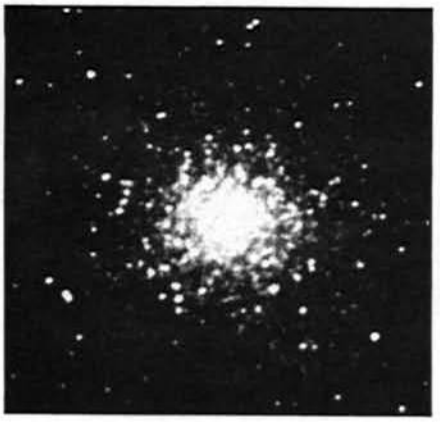
Thirteen degrees southeast of NGC 6426, but still more northerly than most Ophiuchus globulars, lies small and faint **NGC 6517**. Again we are fortunate to have nearby naked eye stars: NGC 6517 is approximately equidistant between Nu (ν) and Tau (τ) Ophiuchi. When you locate NGC 6517 you'll immediately see the sharp difference between it and NGC 6426. While both are small and faint, NGC 6426 is even and diffuse (class IX), and NGC 6517 shows a pronounced central condensation (class IV). Still, it is unlikely that any backyard telescope can resolve more than a few stars in either globular.

One of the strangest globulars in Ophiuchus is **M107** (NGC 6171). At 17.1 kpc (55,700 ly), it is more distant than M14 and much farther away than M10 and M12. Of Shapley class X, M107 is one of the least condensed globulars in the sky. In Steve Gottlieb's 8-inch SCT a grainy halo surrounds the bright core, and in his 13.1-inch he resolves all but the core. In instruments of 18-inches' and up, M107 takes on an unusual appearance. The central region spans about 3′, and resolves into many stars of varying brightnesses. A dark ring surrounds the core, and is in turn surrounded by another ring of faint stars, broken on the north side. The total diameter is as much as 6′ or 7′. This is an excellent globular for careful study on a fine, dark night.

The remaining 13 Ophiuchus globulars all cluster in a small square of sky about 10° on a side.







Top: M10 — paired with M12 and just below naked eye visibility. Photo by Lee Coombs. Middle: M12 — more difficult to resolve and farther away than M10. Photo by Martin Germano. Bottom: M14 — a smaller, rounder version of Omega Centauri. Photo by Martin Germano.

Unfortunately, the square's average declination is −25° — about the same as Antares' — which means that for the best views you will have to observe at 17 hours sidereal time, when the objects are on the meridian and as high in the sky as they ever get. Start with the small tight triangle formed by **NGC 6342**, **M9** (NGC 6333), and **NGC 6356**. These three globulars easily fit in the 3° field of my 4.25-inch f/4 finder; all are visible at 16x, though NGC 6342 is faint. The brightest of the three is, of course, M9. With 10-inch or larger apertures it is possible to resolve this cluster fully on dark clear nights, since the 25 brightest stars are about magnitude 15.8. I find M9 to be about 5′ in diameter and more condensed than its Shapley class (VIII) indicates. The dense core contains about 10 stars noticeably brighter than the rest and is slightly asymmetrical. M9 is one of the nearest globulars to the center of our Galaxy, being located perhaps as little as 2 kpc from the nucleus (and 12.8 kpc or 41,700 ly from us). A large, dark cloud of dust and gas lies between us and the cluster, partially obscuring the stars on its southwestern side — this is known as Barnard 64 and may be visible in a low power eyepiece. Lord Rosse first noticed this darkening in 1851 and described M9 as " . . . outline not round; on south side is an outlying portion separated from the chief portion by a dark passage."

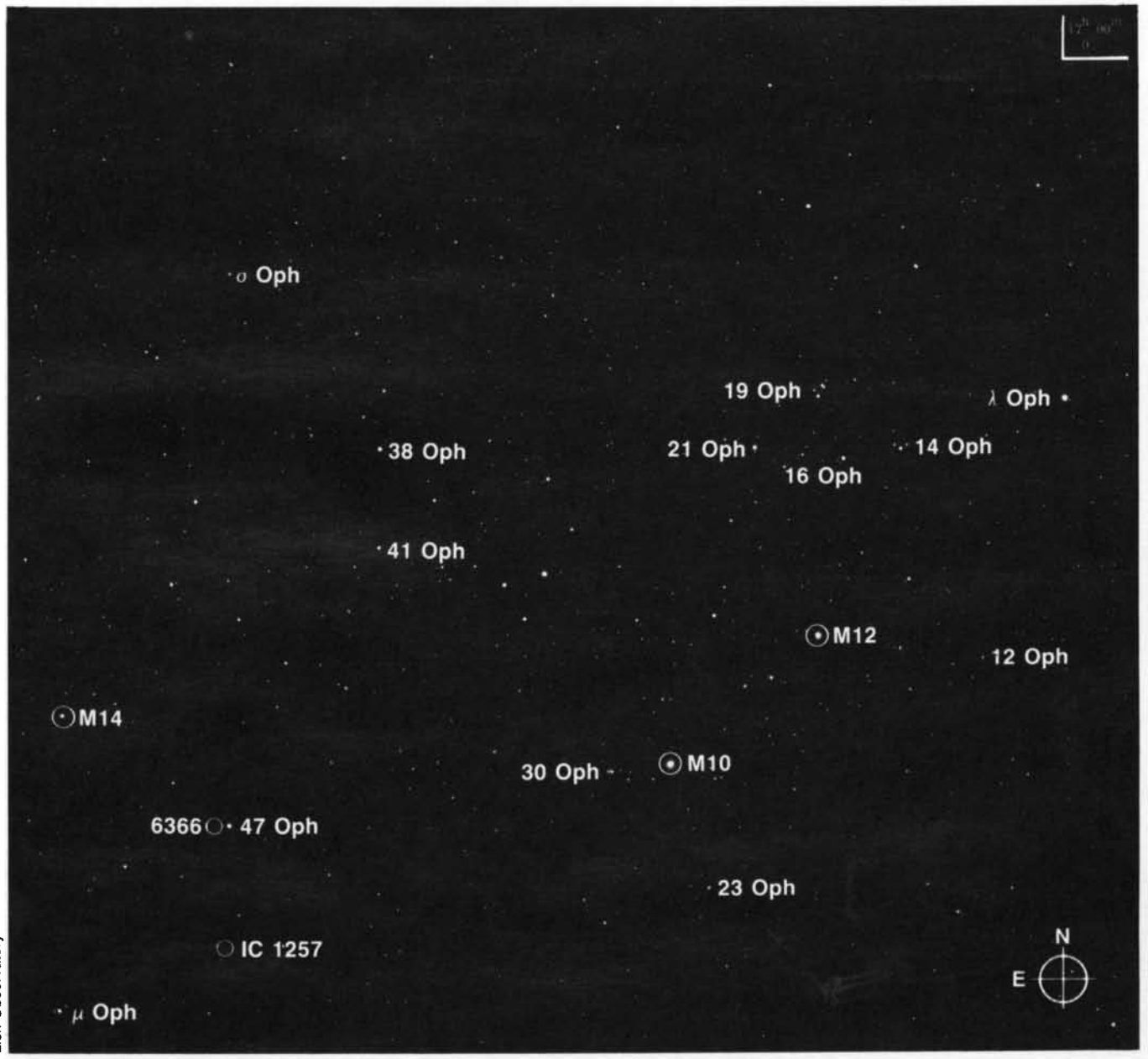
After you examine M9, compare it to NGC 6342, which lies just 1.2° southeast, and NGC 6356 the same distance to the northeast. NGC 6356 is the brighter of the pair, shining at about magnitude 8.5. It is an extremely condensed globular (class II), and even in large instruments looks like a small compressed snowball with ill-defined edges — there is a hint of resolution in the 18-incher. NGC 6342 is also highly condensed (class IV), but is nearly two magnitudes fainter than NGC 6356 and only about one half the apparent size. It appears to be just over 1′ diameter in my 18-inch scope, and is not resolved. The Milky Way background behind these three globulars is extremely rich and beautiful, indicating huge amounts of interstellar material that must lie along that line of sight!

If you now sweep due south about 7°, you will find a small group of naked eye stars centered on third magnitude Theta [θ] Ophiuchi. If the night is clear and dark, you may see the enormous dark stain of the "Pipe Nebula" (Barnard 78) just to the south. It is a mass of dust and gas so dense that it blots out the Milky Way entirely. This region of the sky is just a few degrees west of the core of our Galaxy, so it is not surprising to find it littered with globular clusters. Nine lie within 5° of Theta Ophiuchi, including bright M19 (see below).

Four globulars approximately form a line stretching east to west just above Theta. **NGC 6401** is the most easterly, and is obscured by nearly three magnitudes. In large telescopes the effects of the intervening dust show as dark areas or mottling, but no backyard instrument is likely to resolve the group. **NGC 6325** lies almost exactly 5° west, and while it appears nearly twice the size of 6401's 1.5′ diameter, it is over a magnitude fainter and much looser (Shapley class X). Steve Clougherty, a Boston-area amateur, found 6325 extremely faint in his 8-inch f/6 Newtonian. Under dark Vermont skies, the center of the cluster appeared granulated, but he couldn't resolve the cluster, even with averted vision. Ten-inch scopes may yield some resolution, though. Heading another 3° west and a little north, we next come to **NGC 6287**. This is the brightest and largest of the four and should be easily visible even in small telescopes. As with **NGC 6325**, some resolution is possible on the cluster's edges. The last globular, NGC 6235, lies another 3° due west. It is small, condensed, and pretty faint. While it should be easy to find in a 6-inch telescope, amateur scopes cannot resolve it.

After examining these four difficult objects, you may want to relax with bright and easy **M19** (NGC 6273). Located 3° due east of the 5th magnitude double star 36 Ophiuchi, M19 glows at magnitude 6.6 and is at the absolute limit of naked-eye detection. Messier discovered this object in 1764, cataloguing it as a "nebula without star . . . diameter 3′." Twenty years later William Herschel resolved the cluster, revealing its true nature; his son John found it "Superb! A globular cluster, very bright, round, diameter 10′. Resolved into stars of 14th, 15th, and 16th magnitude." John Herschel's description seems strange, since M19 is not round but rather distinctly oval-shaped, even in telescopes as small as 3-inches' aperture. It is also smaller than his estimate of 10′, with a diameter no greater than 9.3′ on long-exposure photographs (and a smaller diameter visually). However, the first part of his description is correct — M19 is indeed a superb sight on a good night, with a wealth of detail set against a dense, starry background.

From M19 move just 1.5° due east — halfway to 36 Ophiuchi — and you should find the fairly bright globular **NGC 6293**. This object has an integrated magnitude of 9.5 and should appear about 2′ in diameter, although photographs show it to be nearly twice that size. About 2° to the other side of 36 Oph, at the end of a short chain of 7th and 8th magnitude stars, lies **NGC 6355**. This globular is much fainter and smaller than 6293, but is still easy to



Lick Observatory

locate by following the line of stars from 36 Oph. NGC 6355 is dim and elusive in an 8-inch telescope, despite its total magnitude of 10.5. The best views come with larger telescopes, but even then 6355 is unlikely to reveal more than a small circular patch about 1′ in diameter.

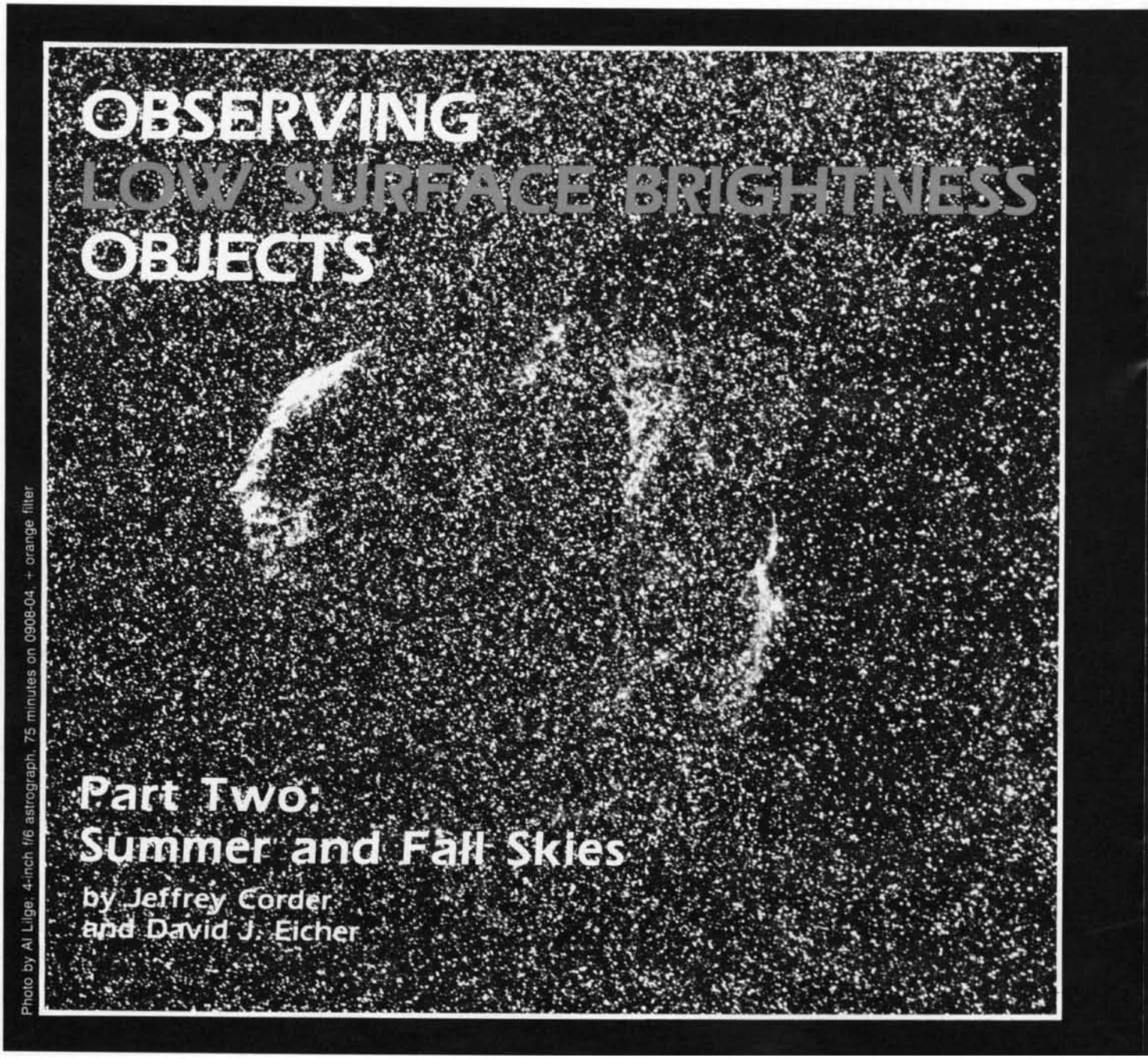
Two of the three remaining Ophiuchus globulars lie due south of 36 Oph. A mere 1.5° south of the star is **NGC 6316**, a 10th magnitude object about 1′ in diameter. A 6-incher shows this object with averted vision, although it is small and featureless. Going another 1.5° south you may spot the second most southerly of all Ophiuchus globulars, **NGC 6304**. Were it not so far south, this globular would be an easy mark: it shines at about 10th magnitude and measures 1.6′ across.

The most southerly globular in Ophiuchus is **M62** (NGC 6266), which lies so close to the Ophiuchus/Scorpius border that some observing guides include it as a resident of Scorpius; it is not, however. Found about 7° southeast of Antares, M62's 8th magnitude core is easily spotted in any finder telescope. M62 is an unsymmetrical cluster whose elongated shape, like M19's, is easy to spot. At high powers in a 6-inch scope, M62 shows a mottled structure but little resolution. Telescopes of 16-inches' aperture or more should resolve its outer parts, as M62's 25 brightest stars glow at about 15th magnitude.

The last of the globular clusters in Ophiuchus lies about 1.5° due north of M19, near two 6th magnitude field stars. **NGC 6284** is quite easy to find, though its integrated magnitude is only 10.5. In an 8-inch or larger instrument it should appear about 1.5′ in diameter, round, and with a fairly bright nuclear region. With larger apertures and high powers, full resolution should be possible.

The globulars of Ophiuchus offer summertime observers one of the finest chances to see different types and brightnesses of our Milky Way's population of globular star clusters. How much do different aperture telescopes show of these remote balls of stars? How small an aperture can resolve the outer parts of fainter globulars or show detailed dark markings amidst the inner workings of the bright clusters? *Deep Sky* is very interested in hearing your observations of the Ophiuchus globulars. Send 'em in to the editor.

Jim Meketa is an avid amateur deep-sky observer active in several specialties in observing. By profession, he manages a financial consulting firm in Newton Centre, Massachusetts.

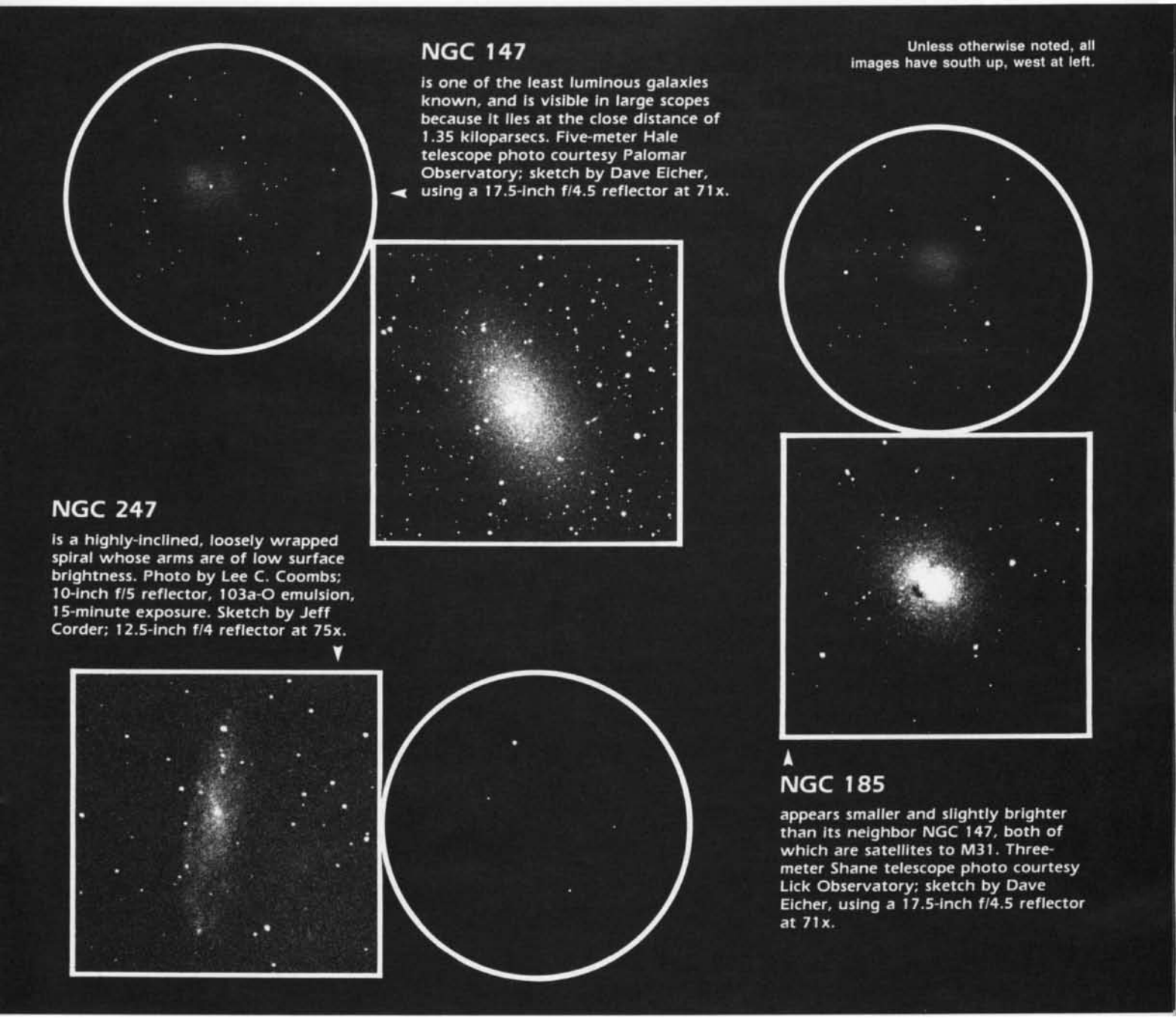

OBSERVING
LOW SURFACE BRIGHTNESS
OBJECTS
Part Two:
Summer and Fall Skies
by Jeffrey Corder
and David J. Eicher
Photo by Al Lilge. 4-inch f/6 astrograph. 75 minutes on 0908-04. + orange filter

Of all of the types of sky objects for backyard observers, low surface brightness (LSB) objects hold the biggest challenge. Many of them have large total brightnesses — the Veil Nebula, the North America Nebula, the Helical Nebula — but their light is so spread out that little "conveniently sized" pieces of a few arcminutes diameter are pretty dim and hard to detect through the telescope. But not to worry; the outlook is bright. Easily available and relatively inexpensive large telescopes, deep-sky filters, and high-tech eyepieces have recently appeared on the scene, proving highly effective in revealing LSB objects when operated under dark, clear skies.

In DEEP SKY 6, the first part of this article provided information on 16 low surface brightness objects of the winter and spring skies. Now we'll extend our list of challenging LSB nebulae and galaxies to the summer and fall skies, offering another 25 such targets.

Two fellow members of the Local Group of galaxies are **NGC 147** and **NGC 185**. Both of these objects are satellite galaxies to M31, the Andromeda Galaxy, although they lie some 7° to the north in Cassiopeia. The two are separated by 58′, making them difficult to view together in a low-power field. Each is elusive: NGC 147 measures 12.9′ x 8.1′ and has a total magnitude of 9.5, while NGC 185 covers 11.5′ x 9.8′ and softly glows at magnitude 9.2. As galaxies go, these two are tiny: they are relatively large in the sky because they lie only 670 kpc away. NGC 147 sports a mean surface brightness of 14.5; NGC 185's is slightly better at 14.3. Though we know of confirmed observations of these galaxies made with a 2-inch refractor, you'll probably need a 6-inch with a wide field to detect either galaxy. (The 2-inch had a 40mm eyepiece and was located in dark central Kansas.) A blue-receptive nebular filter may help as well. Under reasonably good country skies — 30 miles outside of Milwaukee — both galaxies are easily noticed with a 17.5-inch telescope.

The **Andromeda Galaxy** itself is hardly thought of as a low surface brightness object — but it is. M31's integrated magnitude of 3.5 makes it rank behind only the Magellanic Clouds as the brightest galaxy, and makes it



Unless otherwise noted, all images have south up, west at left.

NGC 147

is one of the least luminous galaxies known, and is visible in large scopes because it lies at the close distance of 1.35 kiloparsecs. Five-meter Hale telescope photo courtesy Palomar Observatory; sketch by Dave Eicher, using a 17.5-inch f/4.5 reflector at 71x.

NGC 247

is a highly-inclined, loosely wrapped spiral whose arms are of low surface brightness. Photo by Lee C. Coombs; 10-inch f/5 reflector, 103a-O emulsion, 15-minute exposure. Sketch by Jeff Corder; 12.5-inch f/4 reflector at 75x.

NGC 185

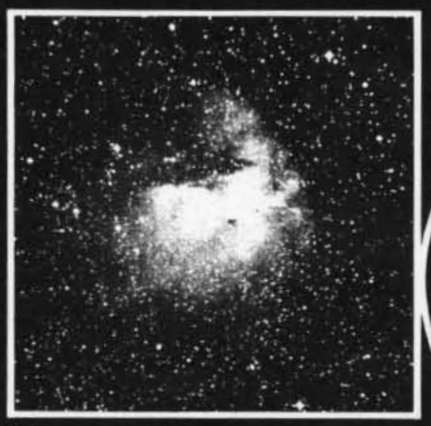
appears smaller and slightly brighter than its neighbor NGC 147, both of which are satellites to M31. Three-meter Shane telescope photo courtesy Lick Observatory; sketch by Dave Eicher, using a 17.5-inch f/4.5 reflector at 71x.

easily visible to the naked eye as a patch of nebulosity. How can M31 be considered an LSB object? A great deal of its light emission comes from its nuclear region, the part visible in finders and little scopes as a large yellowish-white oval of light. The galaxy's spiral arms, however, have a much lower surface brightness — perhaps 13.4. Thus the spiral arms can be traced out to a length of about 2.5° with large apertures (they extend to 4.5° with microdensitometer plate scans) — and while you're in the area, don't forget to look at M32, NGC 205, the star cloud NGC 206, the galaxy's dust lanes, stellar nucleus, and, if you have a finder chart (see the March 1981 *Deep Sky Monthly*), the several dozen bright globulars hovering about the galaxy's nucleus.

NGC 246 is a large ring-shaped planetary nebula in Cetus. It is one of the most detailed such nebulae visible to northerners, as its incomplete ring of low surface brightness gas shows knotty brightenings and a well-defined shape. The 12th magnitude central star is easily visible, as are four other bright stars which lie in the immediate vicinity. The nebula measures 4.0′ x 3.5′ in extent, and its mean surface brightness is around 13.5. A 6-inch scope shows this object as a faint blob of greyish light, lacking any perceivable detail. A 12-incher, though, shows structured nebulosity with varying shades of intensity. Larger scopes yet provide an impressive view of NGC 246 under dark skies.

Lying only 3.5° north of the bright galaxy NGC 253 is the low surface brightness spiral **NGC 247**, a galaxy that offers a challenge to observers with adequate southern horizons. NGC 247 has an integrated magnitude of 8.8, but its great angular dimensions of 20.0′ x 7.4′ make its surface brightness something like 14.1. The galaxy's core is pretty condensed and appears like a fuzzy star-like spot of grainy light. The spiral arms, however, are difficult: a good 8-inch scope under dark skies may be required to spot them.

The large and very difficult emission nebula **NGC 281**, which lies just 1.5° east of the star Alpha (α) Cassiopeiae, has a surface brightness of around 13.0, making the brighter parts of it visible with small telescopes under ideal

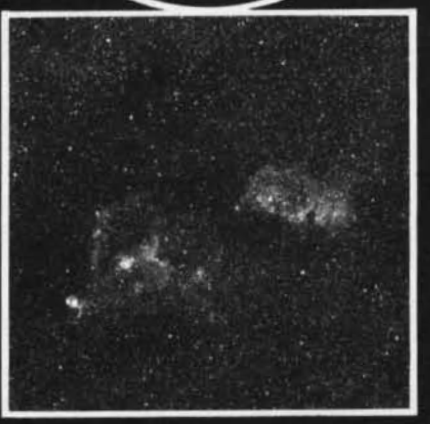


NGC 281

is a large dim emission nebulosity complex in Cassiopeia that lies about 2 kiloparsecs distant. Nebular filters help tremendously with seeing this object. Photo by Lee C. Coombs; 10-inch f/5 reflector, 103a-E emulsion, 15-minute exposure. Sketch by Richard P. Wilds; 2-inch f/12 refractor at 15x.

IC 59 and IC 63

are two emission nebulae whose surface brightnesses are something like 15. They lie within the same telescopic field as Gamma [γ] Cassiopeiae, making spotting them tremendously difficult. Photo by Lee C. Coombs; 10-inch f/5 reflector, 103a-E emulsion, 15-minute exposure. Another object for which *Deep Sky* has no sketched records. Someone help us investigate!



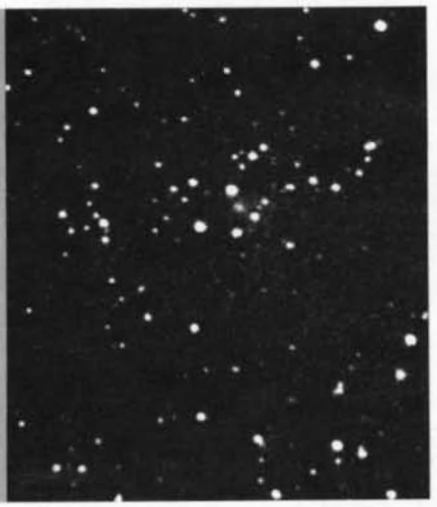
IC 1805 and IC 1848

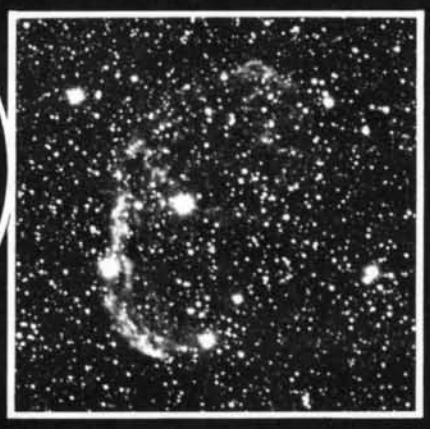
are two huge emission nebulae in Cassiopeia with low surface brightnesses. The fainter of the two, IC 1805, measures over two degrees across — IC 1848 is brighter and occupies 1.0° x 0.5°. Nearby are the faint infrared galaxies Maffei 1 and Maffei 2. Photo by Al Lilge; 4-inch f/6 astrograph, 4" x 5" hypersensitized TP 2415 plate, yellow filter, 120-minute exposure. *Deep Sky* has no sketches of this object: someone make one and send it to us!

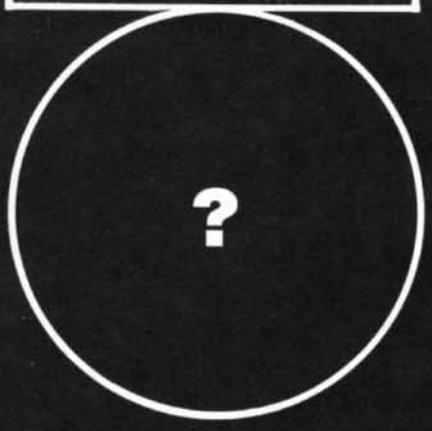
A Challenge for Astrophotographers

In 1968 the Italian astronomer Paolo Maffei found an unusual object lying near the giant emission nebula IC 1805 in Cassiopeia, at 2h 36.3m, +59° 39′ (2000). The object appeared bright at long wavelengths — especially in the infrared — but was a dim smudge on photographic plates. Maffei found a second, fainter object nearby, and called the objects Maffei 1 and Maffei 2, respectively. In 1971 Hyron Spinrad determined that Maffei 1 was a giant galaxy (thought to be elliptical at first, and now thought to be lenticular) hiding behind the thick obscuring couds of Milky Way dust.

It turns out that Maffei 1 contains about as much mass as the Milky Way — 2 trillion solar masses — and lies only 1000 kiloparsecs distant, making it an outlying member of the Local Group of galaxies. If it were out of the Milky Way plane, it would rival M33 in brightness. Our galaxy's blanket of dust dims Maffei 1 by at least five magnitudes, and gives it a surface brightness of about 19! Martin Germano's photograph shows Maffei 1 as a condensed smudge; it is a 40-minute exposure on 103a-F, made with an 8-inch f/10 SCT. It is possible to photograph the galaxy with an amateur scope, but don't try to find it visually.





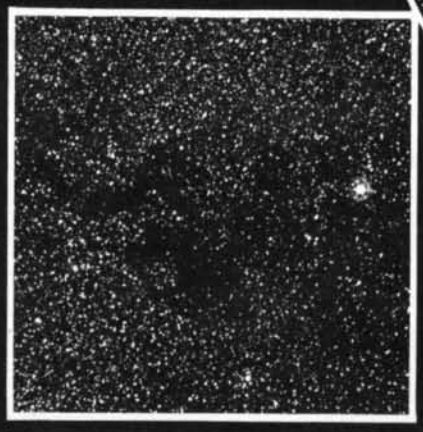


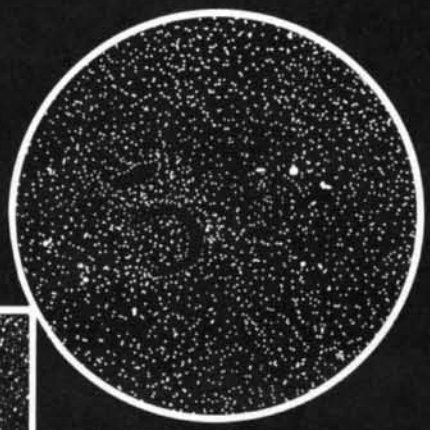
NGC 6888

is one of a handful of reasonably bright supernova remnants in the sky. Its surface brightness is about 14, and it is irregularly lit. The responsible star, a Wolf-Rayet object, is not easily observed. Photo by Alfred Lilge; 12.5-inch Ritchey-Chretien reflector, 098-04 emulsion, 120-minute exposure. Sketch by Dave Eicher; 7 x 50 binocular view at the 1983 Texas Star Party.

IC 4604

is otherwise known as the great Rho [ϱ] Ophiuchi Nebula, as its subtle reflected starlight originates from the bright double star ϱ Oph. Photo by E.E. Barnard, who used the 10-inch Bruce photographic telescope at Yerkes in the early 1890s. This is one of the more difficult objects in this series, and we do not have a sketch of it. We would be interested in hearing of observers' reports of this nebula.





Barnard 143

is one of the largest and most easily observed of the dark nebulae; it has no surface brightness, but is recognizable by the lack of rich Aquila Milky Way stars within its boundaries. Photo by John Sanford; 5.5-inch f/1.65 Schmidt camera, Tri-X pan, 10-minute exposure. Sketch by Dave Eicher; 8-inch f/5 SCT at 35x (focal reducer).

conditions. NGC 281 measures fully as large as the Moon, so it is possible to glimpse this feeble object using a pair of large binoculars — providing the Moon itself is below the horizon!

Way down south at −37° declination is the large SA(s)d-type spiral galaxy **NGC 300**, which is a real problem object for northern observers. According to Gerard de Vaucouleurs of the University of Texas, NGC 300 is inclined 42° to our line of sight, which gives it an appearance like that of M33 in Triangulum. NGC 300's blue magnitude is an impressive 8.7, but it is spread over 20.0′ x 14.8′. This makes the mean surface brightness of its spiral arms about 14.7, and this dimness is further increased by the galaxy's far southern declination. Observers in the southern U.S. or other regions relatively close to the equator will find that NGC 300 is a fascinating object.

IC 59 and **IC 63** are two large, low luminosity emission nebulae adjacent to the bright variable star Gamma (γ) Cassiopeiae. These objects shine by fluorescence caused by energy from Gamma, which fluctuates between magnitudes 1.6 and 3.0. The nebulae are rather difficult to observe, owing to the fact that they measure 10.0′ x 3.0′ (IC 59) and 10.0′ x 5.0′ (IC 63) across and have surface brightnesses of about 15.0. Telescopes in the 14-inch to 20-inch are capable of showing ICs 59 and 63, though they are elusive and require dark skies. A good nebular filter can make the difference with this object.

Considerably easier to detect than the γ Cassiopeiae nebulosities are two huge regions of stars, dust, and emission nebulosity on the southeastern end of the same constellation. These are **IC 1805**, involved with the bright star cluster Melotte 15, and **IC 1848**, which harbors a smaller and dimmer open cluster. IC 1805 has a total magnitude of about 9, but covers 150.0′ x 130.0′ — a considerably larger area than, say, the Andromeda Galaxy. Its surface brightness is probably about 13.5, so it is visible as a large hazy patch, lacking detail, in telescopes sporting wide fields of view. IC 1848 is somewhat brighter — with a magnitude of 8 and surface brightness of 13.0 — so its 60.0′ x 30.0′

Summer and Fall Low Surface Brightness Objects

Type	Designation	R.A. (2000) Dec.	Mag	SB	Size	Con
§E	**NGC 147**	**0h33.1m +48°31′**	**9.5_V**	**14.5**	**12.9′ x 8.1′**	**Cas**
	NGC 185	**0h38.9m +48°20′**	**9.2_V**	**14.3**	**11.5′ x 9.8′**	**Cas**
	Satellite galaxies to M31, lying 7° north of it in the sky and separated by 58′. These dwarf elliptical systems lie 670 kpc from us and 80 kpc from M31, and resemble giant globular clusters in composition. **NGC 147**: Diameter = 1.35 kpc; luminosity = 6 million $L_\odot$; Hubble classification =E5 pec. **NGC 185**: Diameter = 0.71 kpc; luminosity = 8 million $L_\odot$; Hubble classification = E3 pec. NGC 147 is intrinsically one of the least luminous galaxies known.					
§	**NGC 224**	**0h42.7m +41°16′**	**3.5_V**	**13.4**	**158.0′ x 50.0′**	**And**
	Messier 31. Included here for its low surface brightness spiral arms, whose longest dimension measures 2° (up to 4.5° using microdensitometer scans). The surface brightness given above refers to the galaxy's arms. Lies at a distance of 670 kpc, and is our "sister spiral" in the Local Group of galaxies. Diameter = 55.2 kpc; mass = 400 billion $M_\odot$; Hubble classification = SA(s)b. Supernova: 1885 (S Andromedae, at about magnitude 6, was the first sighted extragalactic supernova).					
■	**NGC 246**	**0h47.1m −11°53′**	**8.0_V**	**13.5**	**4.0′ x 3.5′**	**Cet**
	Large ring-shaped planetary nebula. Central star = V magnitude 12.0; Vorontsov-Velyaminov classification =IIIb.					
§	**NGC 247**	**0h44.6m −21°01′**	**8.8_V**	**14.1**	**20.0′ x 7.4′**	**Cet**
	Large faint galaxy lying a mere 3.5° north of the bright spiral NGC 253. Hubble classification = SAB)s)d.					
□E	**NGC 281**	**0h53.3m +56°35′**	**8.0_V**	**13.0**	**35.0′ x 30.0′**	**Cas**
	Emission nebula. Illuminated by tight "trapezium"-type cluster ADS 719. Distance = 2 kpc. Brightest star, HD 5005, has V mag. = 7.8, spectral type O6.					
§	**NGC 300**	**0h54.9m −37°42′**	**8.7_B**	**14.7**	**20.0′ x 14.8′**	**Scl**
	Large SA(s)d-type spiral galaxy.					
□E	**IC 59**	**0h53.7m +60°48′**	**?**	**15.0**	**10.0′ x 5.0′**	**Cas**
	IC 63	**0h56.4m +60°33′**	**?**	**15.0**	**10.0″ x 3.0′**	**Cas**
	Two large emission nebulae (consisting of the same cloud but bisected by a region of dust) adjacent to the irregular and bright (B mag. = 1.6-3.0) variable star Gamma (γ) Cassiopeiae.					
□E	**IC 1805**	**2h32.0m +61°28′**	**9.0_V**	**13.5**	**150.0′ x 130.0′**	**Cas**
	IC 1848	**2h51.3m +60°25′**	**8.0_V**	**13.0**	**60.0′ x 30.0′**	**Cas**
	Two huge emission nebulae that are difficult to detect visually. both are wreath-shaped, and IC 1805 surrounds the open star clusters Melotte 15 (V mag. = 7.0; 30 stars in 6′ area) and NGC 1027 (V mag. = 6.7; 150 stars in 20′ area), and the nebulosity IC 1795. The very faint infrared galaxies Maffei 1 and Maffei 2 lie liess than 1° south of IC 1805.					
□R	**IC 4604**	**16h25.3m −23°27′**	**?**	**15.5**	**124′ x 124′**	**Oph**
	Large reflection nebula centered on the bright double star Rho (ϱ) Ophiuchi (mags. = 5.2, 5.9; sep. 3.5″; p.a. 344°, 1959).					
□D	**Barnard 72**	**17h24.0m −23°38′**	**—**	**—**	**30.0′**	**Oph**
	The "S" Nebula, S-shaped dark nebulosity discovered and catalogued by E.E. Barnard late in the 19th century. Lies 1.5° north-northeast of the short-period variable Theta (θ) Ophiuchi (mag. 3.23-3.27).					

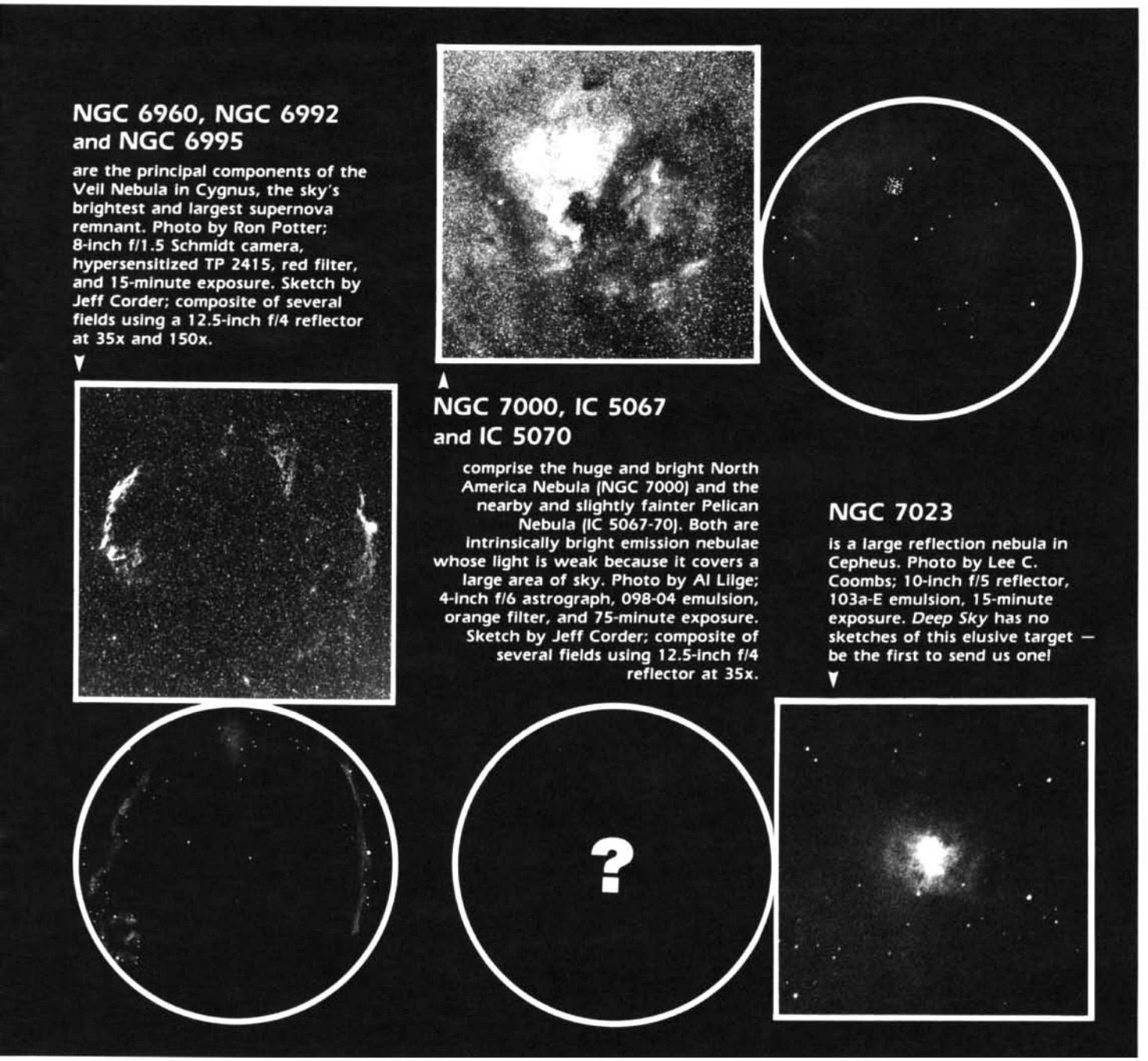
Column 1 = type code: ● = globular star cluster; □E = emission nebula; □R = reflection nebula; □D = dark nebula; ■ = planetary nebula; SNR = supernova remnant; § = spiral galaxy; §E = elliptical galaxy. **Column 2** = name in *Revised New General Catalogue* by J. Sulentic and W. Tifft, and additional lists. **Column 3** = coordinates for epoch 2000.0. **Column 4** = integrated magnitude in V (visual) or B (blue) light. **Column 5** = mean surface brightness (magnitude per square arcminute). This is the best indicator of what you see in your telescope. **Column 6** = angular size in arcminutes. **Column 7** = constellation in which object lies. Data for open clusters from *Catalogue of Open Cluster Data*, 3rd edition, by G. Lynga. Data for globular star clusters from G. Alcaino, *PASP* **89**:491, 1977, and Racine and Harris, *ApJ* **196**:413, 1975. Data for galaxies from de Vaucouleurs and Corwin, *Second Reference Catalogue of Bright Galaxies*. Estimated high-end mean surface brightness data by D. Eicher and B. Skiff.

extent can be glimpsed in the low power eyepiece of a 12.5-inch reflector. Because of their great size, these two nebulosities are tricky ones to spot; a dark, moonless night coupled with a large scope should reveal them. Not far away, about halfway between IC 1848 and the Double Cluster, is the infrared object **Maffei 1** (see box).

Far more challenging than the Cassiopeia nebulosities is the great Rho (ϱ) Ophiuchi nebula, **IC 4604**. This cloud of reflection nebulosity has a surface brightness of about 15.5, making it difficult even with a large scope under black skies. Roughly 2° in diameter, the nebula can be seen as a soft glow centered on ϱ Oph, north of the Antares/M4 area. Using low power is absolutely necessary in attempting to see this object; if the gas spills over one entire telescopic field, it may be difficult to tell whether or not the object is there because there is no dark sky to compare it with. A blue-transmitting nebular filter would certainly help here.

An unusual object in Ophiuchus is the large and distinct dark nebula **Barnard 72**, otherwise known as the S Nebula due to its twisting shape. This patch of dust grains lies 1.5° north-northeast of the short-period variable star Theta (θ) Ophiuchi, and is quite easy to detect on good dark nights. Dark nebulae obviously have no surface brightnesses; they are "surface un-brightness" objects rather than low surface brightness ones. But they are quite enjoyable to identify, and many of the prerequisites for finding LSB objects are needed to find dark nebulae. If the sky is good and dark and you are using a wide field ocular, you should identify this 30′ high figure by the rich Milky Way stars surrounding it, and the absence of any where the dark nebulosity lies. Another dark nebula worthy of finding is **Barnard 143** which, along with its smaller neighbor Barnard 142, forms a giant (30′ diameter) "E" in the Milky Way of Aquila. This dark nebula is on a par with B72, requiring a wide field of view and dark night to make faint field stars show and outline the patch of dust.

With a surface brightness of something like 14.2, **Barnard's Galaxy** in Sagittarius is one of those objects which may be visible with large binoculars under dark skies but which is nearly impossible to detect with a


NGC 6960, NGC 6992 and NGC 6995
are the principal components of the Veil Nebula in Cygnus, the sky's brightest and largest supernova remnant. Photo by Ron Potter; 8-inch f/1.5 Schmidt camera, hypersensitized TP 2415, red filter, and 15-minute exposure. Sketch by Jeff Corder; composite of several fields using a 12.5-inch f/4 reflector at 35x and 150x.
NGC 7000, IC 5067 and IC 5070
comprise the huge and bright North America Nebula (NGC 7000) and the nearby and slightly fainter Pelican Nebula (IC 5067-70). Both are intrinsically bright emission nebulae whose light is weak because it covers a large area of sky. Photo by Al Lilge; 4-inch f/6 astrograph, 098-04 emulsion, orange filter, and 75-minute exposure. Sketch by Jeff Corder; composite of several fields using 12.5-inch f/4 reflector at 35x.
NGC 7023
is a large reflection nebula in Cepheus. Photo by Lee C. Coombs; 10-inch f/5 reflector, 103a-E emulsion, 15-minute exposure. Deep Sky has no sketches of this elusive target — be the first to send us one!
?

telescope's narrow field of view. Catalogued as NGC 6822, Barnard's Galaxy was first detected by E.E. Barnard in Nashville in 1884 — he discovered it visually with a 5-inch refractor. To find Barnard's Galaxy, which measures 20.0′ x 10.0′ across and sports an integrated blue magnitude of 9.3, look 2° northeast of the wide double star 54 Sagittarii. Should the night be black and your telescope capable, you'll see an elongated fuzzy oval patch of weak light, without much central condensation. NGC 6822 is an irregular galaxy — roughly resembling the Large Magellanic Cloud — and a fellow member of the Local Group, lying at a distance of 520 kpc. The galaxy's true diameter is about 3.1 kpc.

One of the few observable supernova remnants in the sky is **NGC 6888** in central Cygnus. This irregular shell of fluorescing gas measures 20.0′ x 10.0′ in extent, although it is not uniformly bright; its total magnitude is probably 11, making its mean surface brightness down at 14. This is a baffling object: invisible in small refractors, mid-sized SCTs, and large reflectors from reasonably dark sites in Ohio and Wisconsin, NGC 6888 appeared bright and obvious in binoculars from the Davis Mountains of Texas. With an object so tenuous and feeble in emitting light, factors like viewing from a site absolutely free of any nearby lights and at the highest possible elevation make a huge difference in what you can see. (At a mile elevation, the dirtiest and murkiest fifth of the atmosphere is below you.)

Among the most popular and sought after of the low surface brightness objects is the **Veil Nebula** complex in southeastern Cygnus. This group of nebulosities arose when, some 30,000 years ago, a star went supernova and blew off a shell of ionized gas. Along with NGC 6888 and the Crab Nebula in Taurus, the Veil is one of the finest supernova remnants in the sky. Its shape is that of a giant cosmic bubble; on each end are dense filamentary streamers of gas marking the expanding bubble — these are NGC 6960 toward the west, and NGC 6992 and NGC 6995 toward the east. Both of these primary filaments are relatively easy to see, being dim but present in a 6-inch

Summer and Fall Low Surface Brightness Objects

Type	Designation	R.A. (2000) Dec.	Mag	SB	Size	Con
□D	**Barnard 143**	**19h40.4m +11°07′**	**—**	**—**	**30.0′**	**Aql**

Along with Barnard 142, a detached segment of the same dust cloud, B143 forms a giant "E" in the sky, about 1.5° west and slightly north of Gamma [γ] Aquilae (mag. = 2.7). Distances to dark nebulae are especially difficult to ascertain, but B143 may be around 770 pc away, its diameter about 6 pc.

§Irr	**NGC 6822**	**19h45.0m −14°46′**	**9.3_B**	**14.2**	**20.0′ x 10.0′**	**Sgr**

Barnard's Galaxy. Visually discovered by Barnard with a 5-inch refractor in 1884. Large irregular galaxy and member of the Local Group, found 2° northeast of the wide double 54 Sagittarii (mags. 5.5, 8.5; sep. 45.6″; p.a. 42°, 1932). distance = 520 kpc; diameter = 3.1 kpc; luminosity = 50 million $M_\odot$; Hubble classification = IB(s)m.

SNR	**NGC 6888**	**20h12.5m +38°25′**	**11.0_v**	**14.0**	**20.0′ x 10.0′**	**Cyg**

Probable supernova remnant.

SNR	**NGC 6960**	**20h45.7m +30°43′**	**7.0_v**	**12.0**	**70.0′ x 6.0′**	**Cyg**
	NGC 6992/5	**20h56.4m +31°42′**	**7.0_v**	**12.0**	**78.0′ x 8.0′**	**Cyg**

The Veil Nebula. Together, NGC 6960, 6992, and 6995 (along with faint middle nebulosity NGC 6979) comprise the brightest parts of the sky's finest example of a supernova remnant. Present expansion speed =45 km/sec; date of explosion = 30,000 years ago. The western half of the loop, NGC 6960, passes through the bright star 52 Cygni (V mag. = 4.0). The Veil's total angular extent is 3.5° x 2.7°.

□E	**IC 5067/70**	**20h48.6m +44°22′**	**9.0_v**	**14.0**	**80.0′**	**Cyg**

The Pelican Nebula. Large irregularly shaped emission nebulosity adjacent to the North America Nebula.

□E	**NGC 7000**	**20h58.8m +44°20′**	**4.5_v**	**13.0**	**120.0′ x 100.0′**	**Cyg**

The North America Nebula. Named by German astronomer Max Wolf, NGC 7000 is one of the outstanding emission nebulae of the entire sky. The nebule lies about 500 pc distant and measures 14 pc across. The loose open cluster NGC 6997 lies within the nebula.

□R	**NGC 7023**	**21h02.0m +68°10′**	**?**	**14.5**	**18.0′**	**Cep**

Reflection nebulosity complex illuminated by a 7th mag. type B5 star.

□E	**IC 1396**	**21h37.5m +57°14′**	**?**	**14.0**	**165.0′ x 135.0′**	**Cep**

Large patch of emission nebulosity involved with a bright star cluster, and lying directly south of the bright (mag. 3.6-5.1) semi-regular variable Mu [μ] Cephei.

■	**NGC 7293**	**22h29.6m −20°48′**	**6.5**	**13.0**	**15.0′ x 12.0′**	**Aqr**

The Helical Nebula. The largest planetary nebula in the sky, the Helix is so spread out that its bright magnitude is misleading. V mag. of central star = 13.4. Distance = 140 pc; diameter = 0.29 pc; mass = 0.1 $M_\odot$.

§	**NGC 7320 et al**	**22h36.0m +33°57′**	**see below**			**Peg**

Stephan's Quintet. Half a degree south-southwest of the bright spiral NGC 7331. Group of five galaxies (NGCs 7317, 7318A, 7318B, 7319, and 7320) whose brightest member — 7320 — may be a foreground object. The types, magnitudes, mean surface brightnesses, and dimensions of the system members are as follows: NGC 7317 — E2, mag. 13.6V, SB = 13.3, dimen. = 1.0′ x 0.8′. NGC 7318A — E2 pec, mag. 13.3V, SB = 13.2, dimen. = 1.0′ x 1.0′. NGC 7318B — SB(s)bc pec, mag. 13.1V, SB = 13.8, dimen. = 1.9′ x 1.3′. NGC 7319 — SB(s)bc pec, mag. 13.1V, SB = 13.9, dimen. = 1.7′ x 1.3′. NGC 7320 — SA(s)d, mag. 12.7V, SB = 13.5, dimen. = 2.2′ x 1.2′.

□E	**NGC 7635**	**23h20.7m +61°10′**	**11.0_v**	**14.0**	**15.0′ x 8.0′**	**Cas**

The Bubble Nebula. Shell-shaped ring of emission nebulosity surrounding several bright stars.

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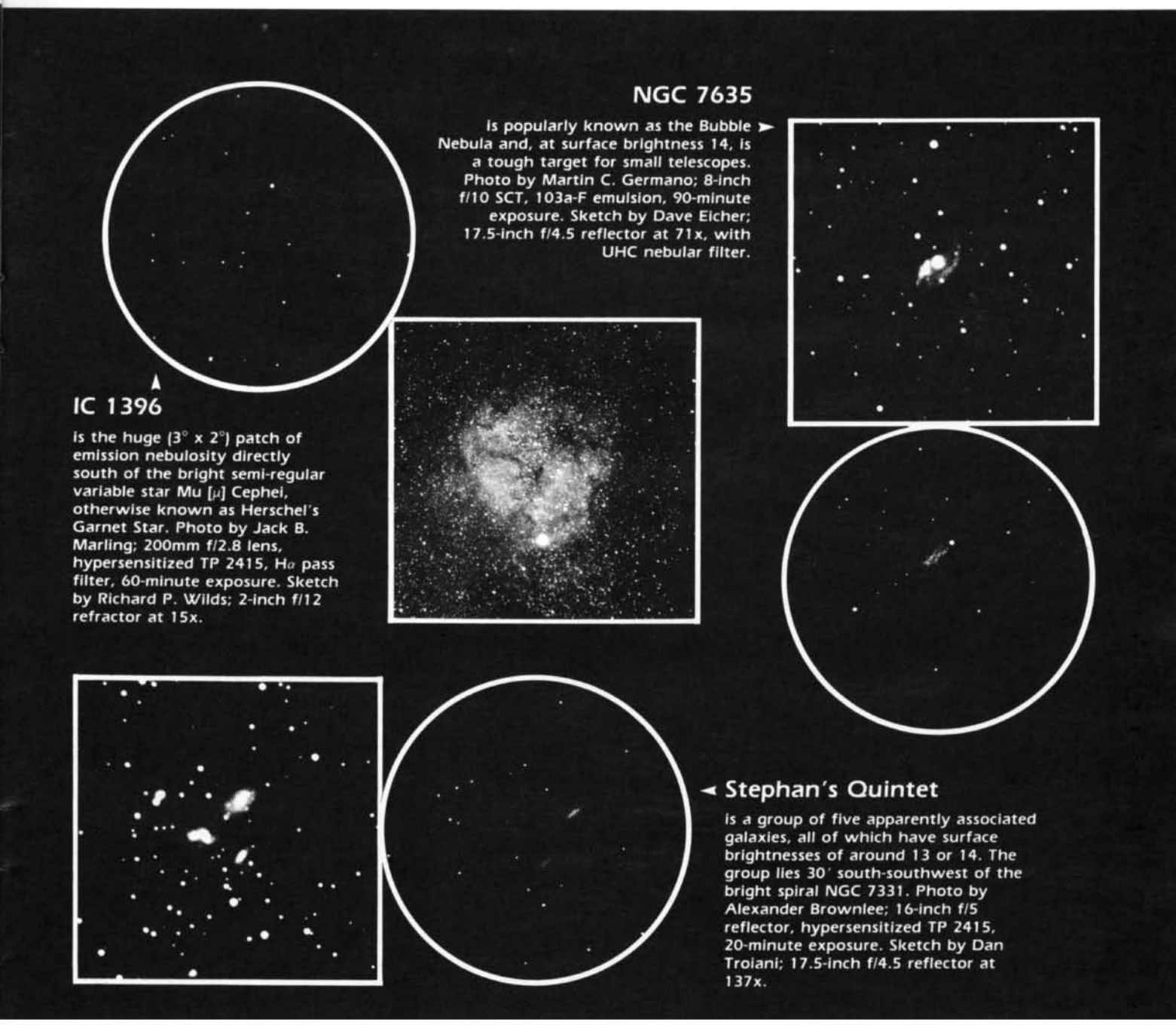
reflector at low power. Their individual total magnitudes are about 7, though their great areas of 70.0′ x 6.0′ (6960) and 78.0′ x 8.0′ (6992-5) cause their surface brightnesses to be about 12. Together, the Veil nebulosity covers an area of 3.5° x 2.7°, and has an integrated visual magnitude of around 6. Of the two "halves," 6992-5 is slightly brighter and more detailed, though 6960 is easier to find because it passes in back of the foreground star 52 Cygni (a 4th magnitude beacon). Nebulosity in between the two main lobes is designated NGC 6979, and is much fainter; it is faintly visible in small scopes as an undefined haze.

Near the region of Deneb in Cygnus is another complex area of nebulosity which contains NGC 7000, the **North America Nebula**, and IC 5067-70, the **Pelican Nebula**. Both are large, bright objects with high total magnitudes but low surface brightnesses; the North America is plainly visible as a nebulous patch to naked eye observers, as its integrated magnitude is probably 4.5. Its sky area of 120.0′ x 100.0′ creates a surface brightness of 13, making pieces of it hard to find in a telescopic field. Here you're looking for subtle nebulosity outlined by surrounding dark nebulae, and unless the night is very good you may have trouble. The Pelican, part of the same emission region and cut off by dark nebulae, has a total magnitude of about 9 and a mean surface brightness of around 14 — it is quite difficult to spot in a telescope but can be surprisingly present in large binoculars.

NGC 7023 is an unusual reflection nebula in Cepheus lit by a hot star and isolated in its field by a complex of dark nebulosity. The star shines at 7th magnitude, which creates the main problem in finding the nebulosity — overpowering glare. The nebulous area measures 18.0' across, so try moving the star around and using averted vision to detect brightness level changes with respect to the sky background itself. A blue-transmitting nebular filter should dramatically improve your chances of finding objects like NGC 7023.

The huge emission nebula **IC 1396** in Cepheus measures 165.0′ x 135.0′ across, making it difficult to observe simply because telescopic fields generally do not cover such hunks of sky. This great gas cloud lies directly



NGC 7635

is popularly known as the Bubble Nebula and, at surface brightness 14, is a tough target for small telescopes. Photo by Martin C. Germano; 8-inch f/10 SCT, 103a-F emulsion, 90-minute exposure. Sketch by Dave Eicher; 17.5-inch f/4.5 reflector at 71x, with UHC nebular filter.

IC 1396

is the huge (3° x 2°) patch of emission nebulosity directly south of the bright semi-regular variable star Mu [μ] Cephei, otherwise known as Herschel's Garnet Star. Photo by Jack B. Marling; 200mm f/2.8 lens, hypersensitized TP 2415, $H\alpha$ pass filter, 60-minute exposure. Sketch by Richard P. Wilds; 2-inch f/12 refractor at 15x.

Stephan's Quintet

is a group of five apparently associated galaxies, all of which have surface brightnesses of around 13 or 14. The group lies 30′ south-southwest of the bright spiral NGC 7331. Photo by Alexander Brownlee; 16-inch f/5 reflector, hypersensitized TP 2415, 20-minute exposure. Sketch by Dan Troiani; 17.5-inch f/4.5 reflector at 137x.

south of the bright semiregular variable Mu (μ) Cephei, otherwise known as Herschel's Garnet Star. (Even if you can't find the nebula, the Garnet Star makes for a fine view.) IC 1396's surface brightness is something like 14, making it a challenging object for practically all instruments. Small telescopes with wide fields generally don't collect enough light to show the object, whereas large telescopes don't have the field to show much of anything. Perhaps an 8-inch or 10-inch f/4 or f/5 instrument under good skies would work best for IC 1396.

An unique little group of galaxies in Pegasus is **Stephan's Quintet**, which consists of five objects of around 13th magnitude. They are: NGC 7317 (mag. 13.6, SB 13.3, size 1.0′ x 0.8′), NGC 7318A (mag. 13.3, SB 13.2, size 1.0′ x 1.0′), NGC 7318B (mag. 13.1, SB 13.8, size 1.9′ x 1.3′), NGC 7319 (mag. 13.1, SB 13.9, size 1.7′ x 1.3′), and NGC 7320 (mag. 12.7, SB 13.5, size 2.2′ x 1.2′). The group lies about 30′ south-southwest of the bright spiral NGC 7331, and is identifiable as a nebulous haze or chain of hazy knots in an 8-inch scope. Larger telescopes reveal that each little galaxy is a distinct entity.

A final object for our low surface brightness observing is the renowned **Bubble Nebula** in northwestern Cassiopeia. Catalogued as NGC 7635, the Bubble lies within the same finder field as the rich open cluster M52, and surrounds a couple of bright stars. It is a hazy wisp of nebulosity some 15.0′ x 8.0′ in extent, though large telescopes show a slightly smaller area of gas. The Bubble's surface brightness is probably down at 14, making it a challenging object for owners of all types of telescopes.

We have enjoyed analyzing a number of low surface brightness objects in this two-part series. Now it's *your* turn. Write and let us know whether you either find or cannot find specific objects we have mentioned. Please address your responses to the editor and mark "LSB" on your envelope.

Jeff Corder is an active observer living in Asheville, North Carolina. He is a frequent contributor; his last article in DSM was part one of "Observing Low Surface Brightness Objects" in Deep Sky 6.

DSM Reports

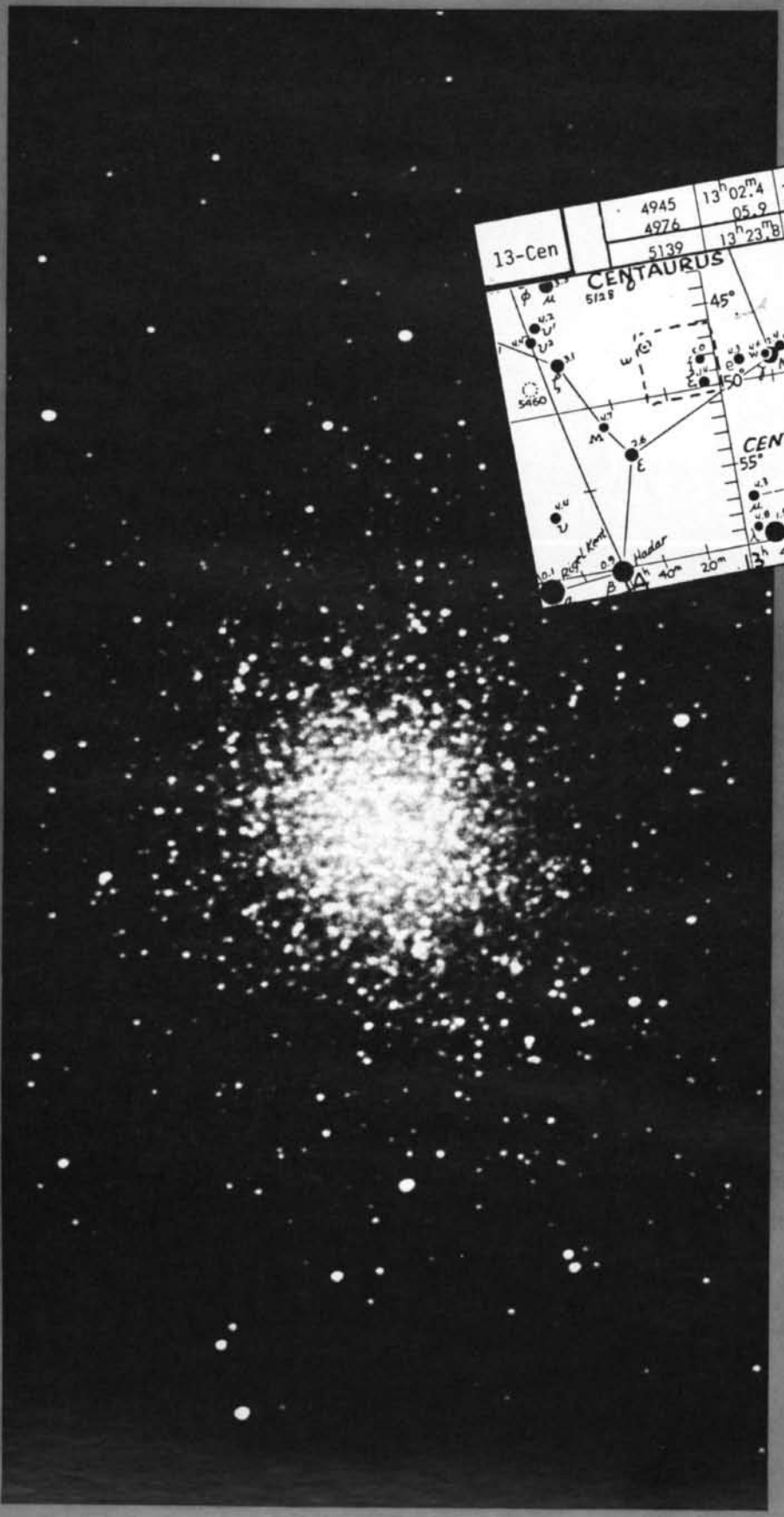
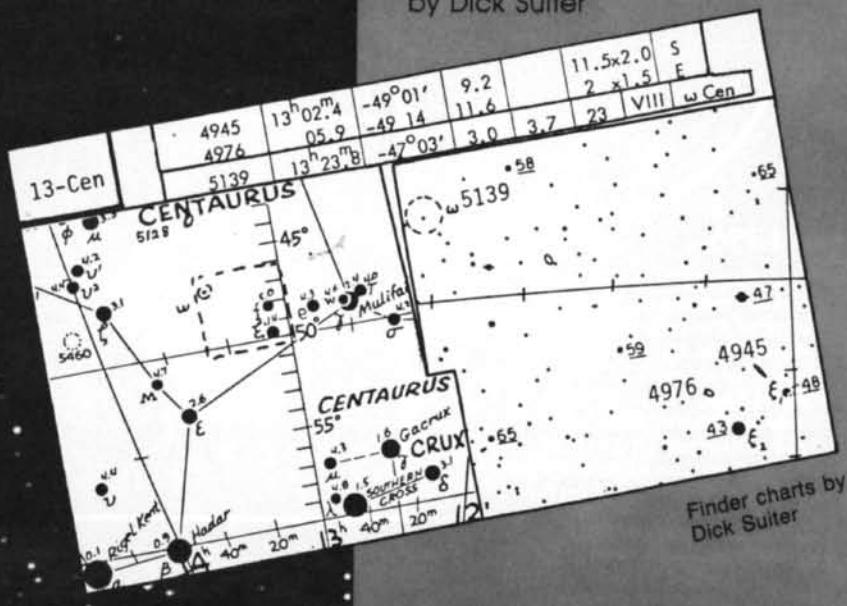


Photo by Martin C. Germano (8-inch f/10; 31 minutes on 103a-F film).

How to Make Deep-Sky Finder Cards

by Dick Suiter



Finder charts by Dick Suiter

Of all my astronomical charts, atlases, books, and paraphernalia, no other source of information is as handy and easy to use as my set of Astro Cards (published by Astro Cards, Box 35, Natrona Heights, PA 15065). It is much easier to carry one Astro Card to the telescope than to haul a heavy atlas or book, and all of the pertinent finding information is in one place. Others must like them too, because they outfit their telescopes with little clips to hold them and tiny LED's to illuminate them — in fact a whole technology has sprung up around these things! Their main fault, if they have any, is that there aren't *enough* Astro Cards. They cover all the Messier list, the biggest and brightest NGC objects, and a few showpiece doubles, but that's about it. They are particularly weak in the southern constellations, and variables get ignored — and after all, even people who don't consider themselves variable star observers like to watch the more spectacular variables such as blood-red R Leporis.

Now wouldn't it be nice if you could reach into a box and pull out a finder card for virtually any deep-sky object you wanted? Well, there is a way to get ahold of these cards, but you have to invest some work and you may have to wait many years before your collection gets big enough to help you find nearly all of the deep-sky objects you want.

The solution? Make them yourself, a few at a time.

You need three basic elements to find objects: 1) a small-scale chart that places you in the constellation and points out what might be called the "pilot star," 2) a large-scale chart that shows many of the stars you'll see in your finder, and 3) a description of the object which includes the coordinates, the object's type (galaxy, globular, etc.), brightness, and angular size.

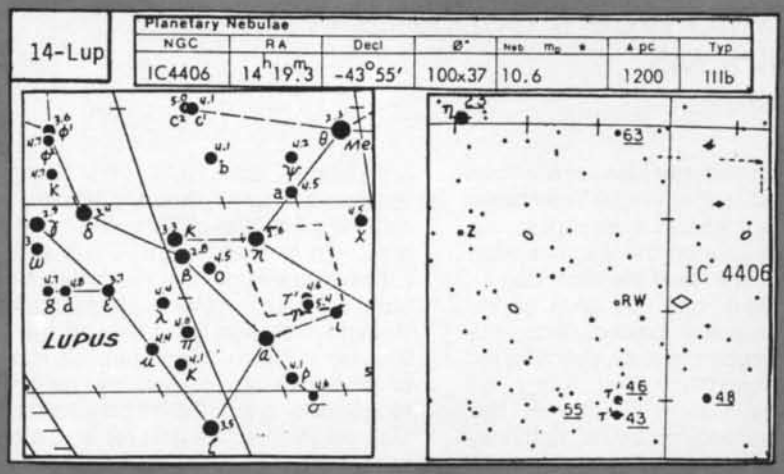
So before you begin you must decide which atlases you want to use and which best fit the task. In the examples with this article, the small-scale map is developed from the *Edmund Mag 5 Star Atlas*. *Norton's* would also work, but the Edmund atlas has the constellation stick figures already drawn in and also labels the NGC numbers. (Unfortunately, *Norton's* employs the archaic Herschel designations.) The scale of the Edmund atlas is about 18.9 arcminutes per millimeter, but any atlas of about this scale or smaller serves the purpose.

For the large-scale chart your choices narrow considerably. You'll want penetration to about ninth magnitude, so that excludes popular atlases such as Becvar's *Atlas of the Heavens* or Tirion's *Sky Atlas 2000.0*, which plot stars to only about seventh magnitude. On the other hand, the photographic atlases (such as those produced by Hans Vehrenberg) go *too* faint and clutter the field with stars that you can't see in your finder.

Best of all are the charts produced for finding variable stars in the *AAVSO Variable Star Atlas*. This atlas isn't perfect — it plots deep-sky objects but fails to label them. This problem is surmountable, although you can't help but wonder why it was done that way. The scale is 4 arcminutes per millimeter. Other atlases that will do are Becvar's *Atlas Borealis*, *Atlas Eclipticalis*, and *Atlas Australis*. These don't plot deep-sky objects and are very expensive, but do reach magnitude 9 and have a nice scale of 3 arcminutes per millimeter.

Finally, for the description of the object you can use a variety of sources, the most common of which is *Burnham's Celestial Handbook*. My examples use Vehrenberg's *Handbook of the Constellations* because its two-column format allowed the catalogue information to be easily squeezed onto a card.

Well, this is all fine and dandy, but how do you make them? First, start with a blank 3" x 5" index card, preferably unlined; if it has lines, turn it over. You draw a little box (about 1 cm by 1.5 cm) in the upper left-hand corner, and in it write the hour number of the right ascension and the abbreviation of the constellation. It helps if you type; but neat printing works just about as well. Then take the appropriate atlas pages and cut them out with an eye toward



clarity. (You could also use photocopies.) It doesn't do any good to have a card that isn't crystal clear as to which star is the "pilot" star. Be sure to include the pilot star on the large-scale atlas cutout. The best situation results when you can place the object between two pilot stars and include both of them on the large-scale cutout, but that is not always possible. Point the cutouts so north is up on both. This makes them consistent with the commercial Astro Cards and squares better with the usual inverted image.

In my examples above you see IC 4406 bracketed by two pilot stars, Eta (η) Lupi and Tau (τ) Lupi. This was lucky, but you'll also run into cases like Omega (ω) Centauri which lies too far from anything else to have a second pilot star. The little dashed box on the small-scale atlas cutout represents the approximate position of the large-scale cutout. Note that I also plotted two other objects on the ω Centauri card — when it's easy and appropriate, make multiple entries on a card.

You put just enough glue on the atlas cutouts to hold them in place. Then cut out the catalogue strip and tack it on in a similar manner. When you've finally assembled it, you'll see that the card wouldn't stand up to five minutes' use. So you have one step left — "toughening" the card. For this final treatment cover both sides of the card with transparent contact plastic, making sure the kind you buy is truly transparent, not translucent or frosty. Finally, trim the plastic to size.

You have probably noticed that the card you have made is different from regular Astro Cards in a number of substantive ways. The most important is your inability to write on it. If you have traditionally made notes of observations on the back, you have two options: a) interleave the finder cards with blank, garden-variety 3" x 5" cards, or b) get one of those pens used for marking the acetate on overhead projections (get a "superfine, waterproof" pen).

But there are advantages to the plastic that outweigh not being able to write on them. Coated cards are dewproof. I have been out on nights when the dew or frost was dropping so rapidly that it was hardly distinguishable from rain. After a few minutes of such an onslaught, any Astro Cards will become limp and in great danger of tearing. But please note that "dewproof" does not mean "waterproof"! If you drop your coated card into water, the liquid will seep in from the edge.

The other difference in these plastic-covered cards is their thickness. You'll probably have to rethink your method of storing them. If you make very many of them, your "term paper" size filing box will no longer be large enough — scout out a stationery store for a larger model.

With my cards, I've attempted to make them resemble Astro Cards, even down to mimicking the little corner box. But you can follow many other plans — for example, if you don't list objects according to r.a. or by constellation but rather file the cards by their principal object, the little box on the corner should contain the object's number rather than the constellation abbreviation. People who find the front side a little cramped might want to put the small-scale atlas on one side and the large-scale atlas on the other. Others might want to dump the 3" x 5" format altogether and switch to 4" x 6" cards. The possibilities are endless.

You'll find that producing these cards is time-consuming and expensive, so for that reason I recommend buying all the available Astro Cards. If they ever extend their line beyond the present limit, I advise you to get the additional cards. There is nothing quite like a real Astro Card produced especially for its purpose. But you needn't rue the work required to make one for an object that isn't on their lists. The effort required to make a deep-sky finder card somehow forces you to remember the object better, and become a better observer because of it.

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Observing Type II Cepheids in Globular M5

by Jim Meketa

The globular cluster Messier 5, known also as NGC 5904, lies 23° southeast of Arcturus, where it straddles the celestial equator on the western edge of the Serpent's Head (Serpens Caput). To the naked eye, this area of the heavens appears barren, with the brightest nearby stars scarcely brighter than third magnitude. Fortunately, the disk of our Galaxy is thin in this direction, affording us a relatively unobstructed view of M5 and into intergalactic space beyond.

With a northern declination of just 2°, M5 is visible from every part of the Earth. With an integrated magnitude of 6.03, it is the eighth brightest globular in the sky (after ω Centauri, 47 Tucanae, M22, NGC 6752, M13, NGC 6397, and M4) and is intrinsically nearly identical to giant M13 in Hercules. It measures 39 parsecs across and probably contains over 500,000 stars. At a distance of 7.7 kpc (and 6.8 kpc from the galactic center), M5 is a little more remote than M13 and nearly as far from us as is the center of our Galaxy. Since a 6-inch telescope resolves the cluster, the stars we see within it must be extremely luminous, giants hundreds of times brighter than the Sun. The brightest are red giants, with absolute magnitudes around −2. At the distance of 7.7 kpc (or 25,000 light-years) they appear no brighter than 12th magnitude — but remember that at the same distance our Sun would be no brighter than magnitude 19.5!

M5 is also an old cluster. Mount Wilson astronomer Halton C. Arp estimates its age to be 13 billion years, more than 2½ times the age of the Earth. Thus, for eons M5 has sparkled in the heavens, a glittering jewel made of thousands upon thousands of stars, each bound to the others by the invisible pull of gravity.

Being of sixth magnitude, and since the bulk of its light comes from a core region less than 5 arcminutes in diameter, M5 should just be visible to the naked eye under perfect conditions, although I know of no sightings. It would appear as a barely discernible "star," nearly a moon-width north-northwest of the 5.3 magnitude star 5 Serpentis.

Even the slightest optical aid immediately reveals M5. In finders and small refractors, it looks like a soft, hazy glow about 5′ in diameter with a brighter core. The minimum aperture needed to resolve the cluster is uncertain. John Mallas, an expert observer with dark skies, found "a hint of partial resolution" with his 4-inch Unitron refractor, while E.J. Hartung, in Melbourne, Australia, says that "outliers may be seen with 7.5 cm [3-inch], and 10.5 cm [4.2-inch] resolves it plainly." Gonzalo Alcaino, in compiling his *Atlas of Globular Clusters with Color-Magnitude Diagrams*, carefully measured the magnitudes of M5's brighter members. He found 14 stars brighter than 13th magnitude (the limit for a 3-inch telescope), 52 stars brighter than 14th magnitude (the limit for a 5-inch), and 119 stars brighter than 15th magnitude (the limit for an 8-inch scope). Thus, M5 is likely to appear "fully resolved" in an 8-inch telescope, although the core region is so compact that it has never been resolved with any instrument.

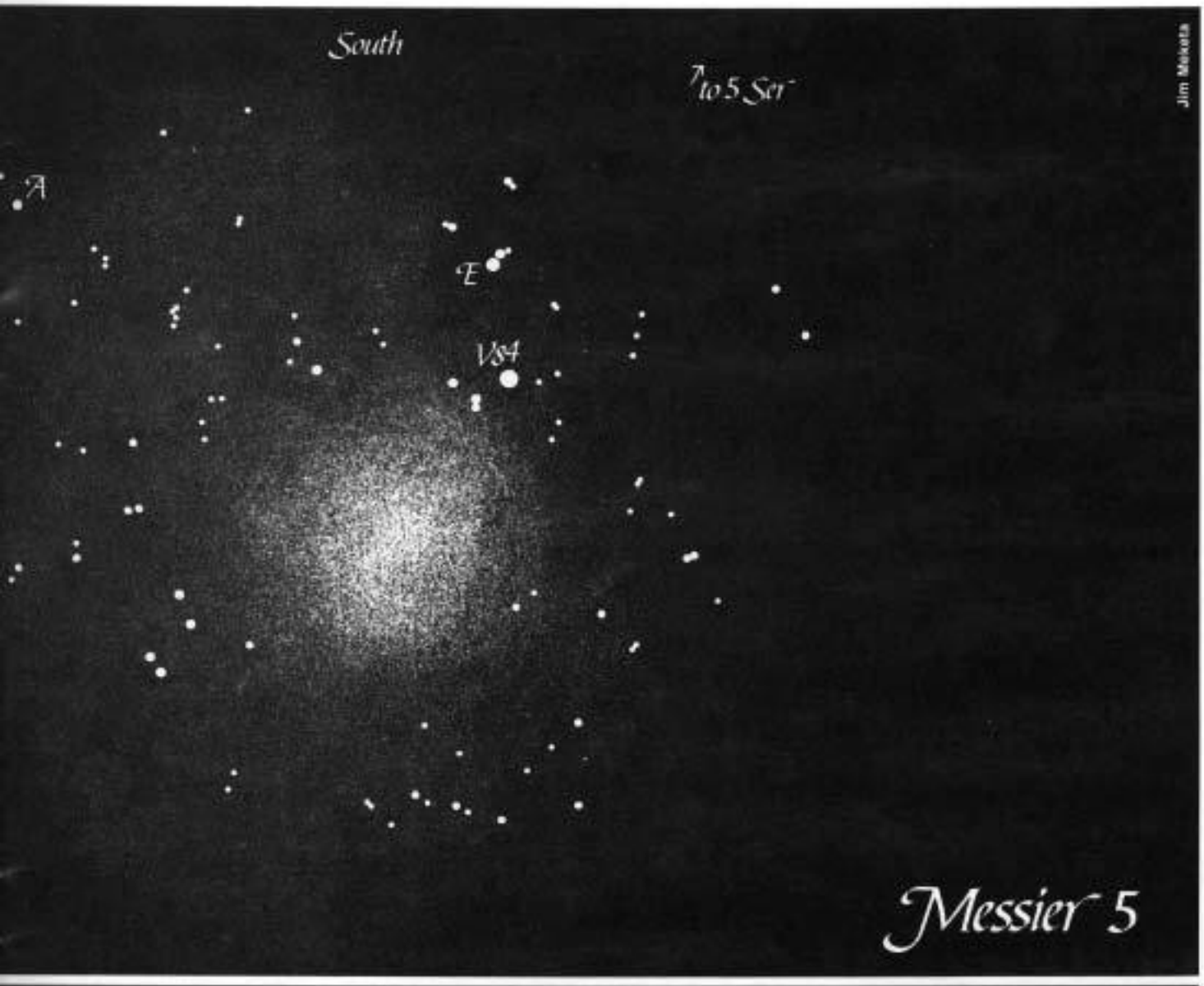
Viewed in a large telescope, M5 is a stunning sight. Robert Burnham, Jr., describes the view in Flagstaff's 40-inch Ritchey-Chretien reflector as "the fireflies of a thousand summer nights . . . frozen forever in time and suspended among the stars." Mary Proctor, using the 40-inch Clark refractor at Yerkes, saw "myriads of glistening points shimmering over a soft background of starry mist, illuminated as though by moonlight."

In common 8-inch telescopes M5 is still a grand sight. Its Shapley concentration class is V, since there is a marked degree of central condensation. (The scale runs from I to XII, with I being most concentrated.) Although its integrated brightness is nearly as great as that of M13, M5 appears much looser and more scattered, with a very irregular distribution of bright stars. The central core is about 2′ in diameter, very bright and extremely condensed, and often appears elliptical or triangular. Surrounding the core, stars and an unresolved haze radiate outward in loose spirals and arcs, making it difficult to tell where the cluster ends. A common description of the shape of M5 is "spidery." (See E.S. Barker's drawing in the Webb Society's *Handbook*, volume 3.) Most amateurs would say the cluster is about 12′ in diameter, while Helen Sawyer Hogg gives a total apparent diameter of 20′. Walter Scott Houston, on the other hand, thinks it can appear as large as 27′. Alcaino, in his very reliable paper "Basic Data for Globular Clusters," *PASP* **89**:491, 1977, lists 17.4′ as the cluster's true diameter.

M5's Cluster Variables

M5 was discovered in 1702 by the German astronomer Gottfried Kirch, but his primitive non-achromatic telescope showed no trace of stars. Resolution of this cluster had to wait another 89 years, until William Herschel was able to construct a speculum-metal mirror large

Above: This finder map has south at top, and shows positions for the two bright Cepheids in relation to field stars of known constant brightness. A = mag. 13.0, B = 12.2, C = 12.8, D = 12.8, and E = 12.0, 12.4. *Right*: The cluster photographed a month apart, showing changes in the Cepheids' brightnesses.


South
to 5 Ser
A
E
V84
Jim Melotte
Messier 5

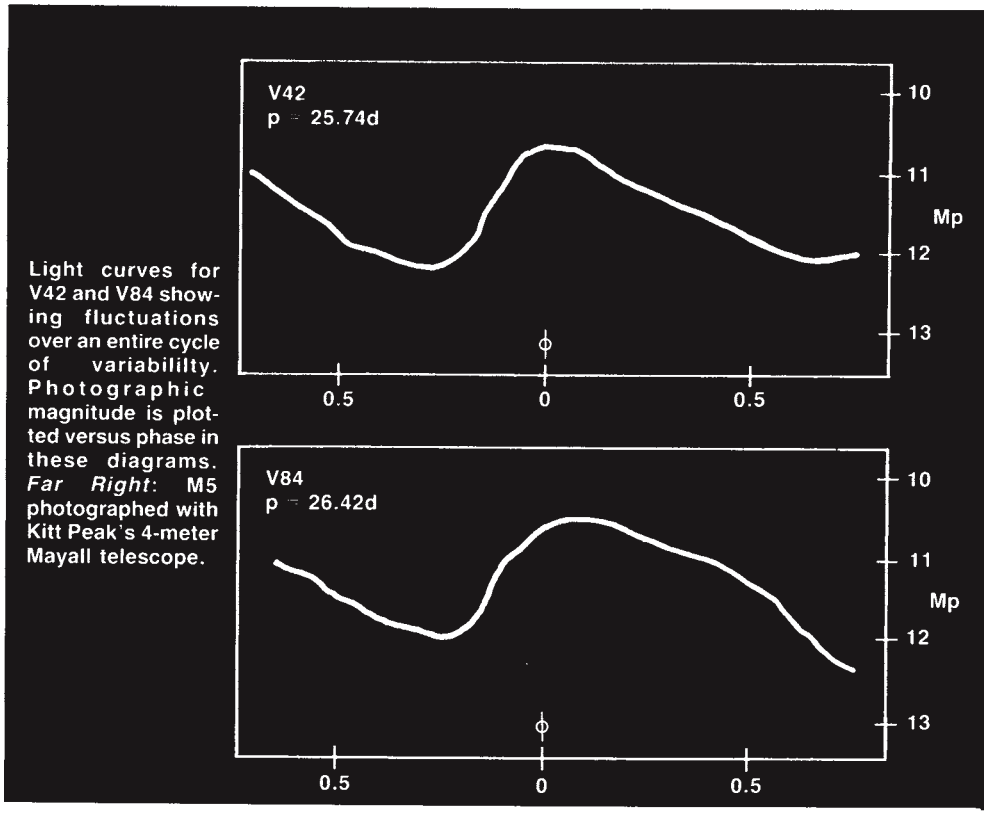
enough to reach well beyond 13th magnitude. Herschel estimated that he could see as many as 200 stars in the central region, although he could not fully resolve the core.

For the next century M5 was viewed innumerable times by astronomers everywhere, amateur and professional. John Herschel, Admiral Smyth, Lord Rosse, and T.W. Webb, among others, wrote about M5, in every case describing it as a noble or superb object, with countless members. Yet all of this study by the most highly trained visual observers failed to detect the fact that at least two of the brightest stars in M5 vary continuously in brightness through a range greater than 1½ magnitudes! Even more surprising, this variation is so great that it can change the appearance of the overall cluster dramatically.

The first variable star in a globular — other than M80's T Scorpii, the nova of 1860 — was found in 1889, when Professor William H. Pickering led an expedition from Harvard College Observatory to what was then called Wilson's Peak, California. Pickering used a 13-inch astrograph to photograph M3 (NGC 5272) on at least five separate dates in May and early June, and he soon noticed the bright Type II Cepheid now known as Variable 154. Pickering reported his discovery in November, leading to an immediate search of other bright globulars by A.A. Common in Great Britain, who soon found six short-period variables (RR Lyrae stars) in M5.

While numerous professionals searched for variables by comparing photographic plates, D.E. Packer studied M5 visually with a 4.5-inch refractor. By comparing drawings that he had made in May 1889 with the cluster's appearance a year later, he noticed that a fairly bright star just southwest of the cluster's core had changed. This star, now known as Variable 42, had been missed by Common's photographic survey, as had the equally prominent Variable 84, which Packer found a year later.

Within a few years the famed American astronomer E. E. Barnard had determined the two variables' periods to within 0.1 day, and had found that they both had a range of 1½ magnitudes. Other photographic surveys, notably those of Solon Bailey of Harvard College Observatory, soon located a total of 97 variables in M5. However, only the two variables discovered visually (V42 and V84) proved to be Population II Cepheid variables — also known as W Virginis stars — extremely luminous stars with periods of about 25 days. All of the rest were RR Lyrae types (formerly called "cluster Cepheids"), which are at least 3 magnitudes fainter intrinsically and which have very short periods of 8 to 12 hours.



Light curves for V42 and V84 showing fluctuations over an entire cycle of variabililty. Photographic magnitude is plotted versus phase in these diagrams. *Far Right*: M5 photographed with Kitt Peak's 4-meter Mayall telescope.

In 1973, Helen Sawyer Hogg published her *Third Catalogue of Variable Stars in Globular Clusters*, covering 108 of the 130 known globular clusters in our Galaxy. Her work indicates that M5 is truly a remarkable globular, since 60% of all of the clusters studied had 10 variables or fewer, and 20% had only one or more. With 97 known variables M5 ranks 5th, behind M3 (212), Omega [ω] Centauri (179), IC 4499 (129) and M15 (111). Further, the two Cepheids in M5 are the brightest known in any cluster except one — Variable number 1 in ω Centauri. As such, they are ideally suited for amateur study.

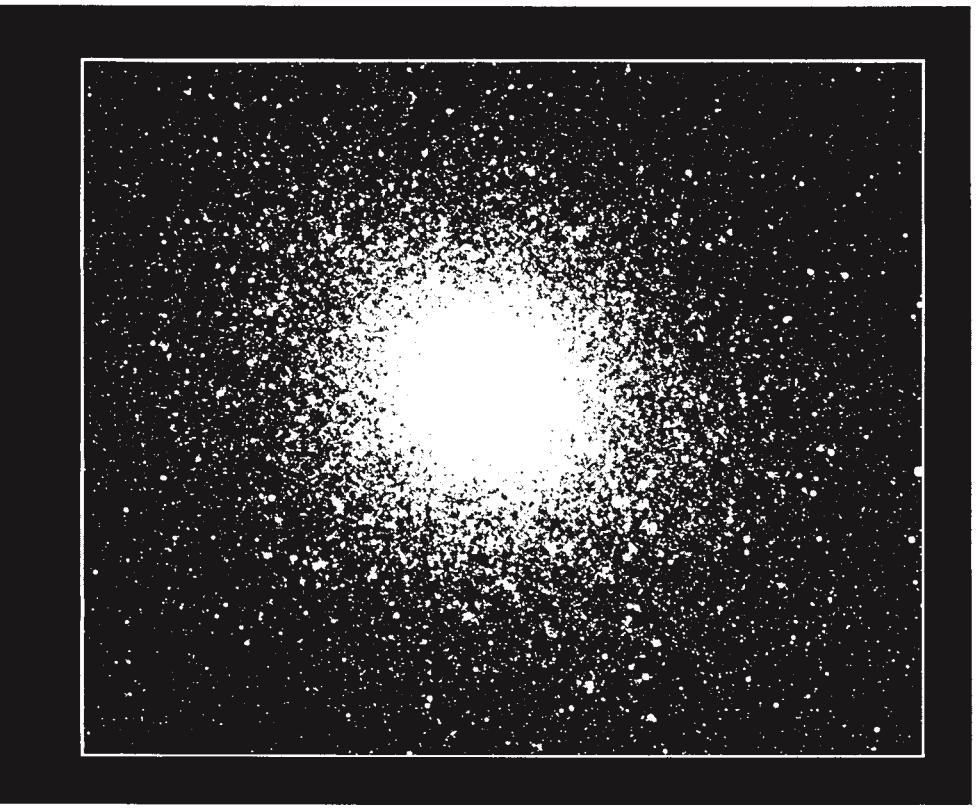
Observing the Variables

The finder chart on page 33 provides locations of M5's Variables 42 and 84, along with magnitudes for several reference stars. Both variables commonly fluctuate between about magnitude 11.2 and 12.7, although they can become as bright as magnitude 10.3 and as faint as 13th. The period of Variable 42 is constant at 25.738 days, while Variable 84 has shown small shifts about its current period of 26.42 days.

To locate Variable 42, start by centering the star 5 Serpentis in your finder (5 Ser is a fine double with a magnitude 10.1 ruddy companion 11.2″ away in p.a. 36°). From 5 Ser move 12 arcminutes due west to a lone star of about 9th magnitude. This star lies 20 arcminutes due south of M5; use it to imagine a north-south line to the cluster. Variable 42 can then be located at the southeast corner of a small parallelogram of faint stars, 3 arcminutes southwest of the core of M5, while Variable 84 is much closer to the core, less than 1 arcminute to the southeast. To help identify Variable 84, note that there is a close, slightly uneven pair of 12th magnitude stars just 30 arcseconds due south of the variable, and that the components of this obvious double lie on a line that points toward the center of the cluster. Take your time and work slowly — compare the chart carefully with the eyepiece view. Don't be discouraged if it takes you several minutes to locate the variables.

Both variables can be seen easily in the short exposure photograph of M5 at the top of page 1781 in Burnham's *Celestial Handbook*. The photograph is oriented with south up, and the parallelogram containing Variable 42 lies in the upper left corner. The double star just south of Variable 84 is also visible, just above and slightly to the right of the core. Keep in mind, though, that photographs usually bear little resemblance to the view in an eyepiece.

To follow both variables through their minima you will need a reflector telescope of at least 6-inches' aperture, although under perfect conditions a slightly smaller refractor might do. Since the two variables are point sources, they will be affected relatively little by light pollution, so a good 8-inch should show their variations even from an urban site. Start by locating the variables and memorizing their positions. Both are among the brightest stars in the cluster even at minimum light, and at maximum



they stand out like small beacons. The peculiar elliptical shape of M5's core and the obvious streamers (particularly the one pointing south toward 5 Serpentis) will help you orient yourself each time you go back to reobserve the cluster. You might also find it helpful to make a drawing of the stars immediately surrounding each variable. Try different eyepieces, since a higher power will darken the background sky and perhaps reveal fainter stars.

The light curves for these variables, made in 1971, indicate distinctly different behavioral patterns. The curve for Variable 42 is sharp and well defined, indicating a single, constant period. The curve for Variable 84 is less distinct, with a greater scatter of measured points. The reason is that Variable 84 shows some of the characteristics of RV Tauri stars, with which there are two cycles of variation superimposed upon one another. This seems to be evidence that different layers in the star's atmosphere are oscillating at different frequencies.

The table below gives predicted dates and times for maxima and minima of the two variables in 1984. Looking at the light curves, you can see that the rise from minimum to maximum is steep, occurring in about 7 days in both cases, while fading is much slower, usually taking about 18 days. Therefore, the change in the appearance of the two stars will be most dramatic during the week just before maximum.

The periods of the two variables differ slightly, causing them to "beat" against one another in a long period rhythm. During the late summer of 1984 the maxima of the two light curves (and the preceeding minima) should coincide for a few months, leading to a changing appearance of the entire cluster.

Predicted Dates of Maximum and Minimum Light

Variable 42		Variable 84	
Maximum	Minimum	Maximum	Minimum
May 20, 1984	May 13, 1984	May 17, 1984	May 9, 1984
Jun 15	Jun 8	Jun 12	Jun 5
Jul 11	Jul 4	Jul 9	Jul 1
Aug 5	Jul 29	Aug 4	Jul 28
Aug 31	Aug 24	Aug 30	Aug 23
Sep 26	Sep 19	Sep 26	Sep 19
Oct 21	Oct 15	Oct 22	Oct 15

However, M5 will sink rapidly into the western sunset in September. Also, remember that all variable stars can do unpredictable things, so don't rely upon the dates too heavily. Here is a bibliography for those who wish to dig up the papers: "The Bright Variable Stars in M5," Christine M. Coutts Clement and Helen Sawyer Hogg, *Journal* of the Royal Astronomical Society of Canada, **71**:281, 1977; "A Third Catalogue of Variable Stars in Globular Clusters Comprising 2119 Entries," Helen Sawyer Hogg, *Publications* of the David Dunlap Observatory, volume 3, 1973; "A Bibliography of Individual Globular Clusters," Helen Sawyer Hogg, *Publications* of the David Dunlap Observatory, volume 2, 1963; *Globular Clusters*, D. Hanes and B. F. Madore, Cambridge University Press, New York, 1978; *Atlas of Globular Clusters with Color-Magnitude Diagrams*, Gonzalo Alcaino, Catholic University of Chile, 1973.

The second *Index Catalogue* lists two deep-sky objects in the same lower power field as M5; both are probably distant galaxies. Some 8 arcminutes due west of the globular, E. E. Barnard located IC 4537 (2000 position: 15h17.5m, +2°02′), which he described as extremely faint, very small, round, and with a brighter middle. On the Palomar Sky Survey plates, 4537 is immediately obvious and seems to match well Barnard's description. Fritz Zwicky assigns a magnitude of 15.6 to IC 4537, but you will probably find it to be brighter visually.

About 10 arcminutes due east of 5 Serpentis, Lewis Swift noted IC 4540 (2000 position: 15h19.8m, +1°47′), which he described as very faint, pretty small, moderately elongated, and with a bright star nearby (probably 5 Serpentis). However, nothing is visible on either the red or blue Palomar plates at the position given by Swift, and Zwicky did not list IC 4540 on his finder charts for the area. I believe that Swift made an error in position, and that he actually found a galaxy that appears on the Palomar survey at a point 9 arcminutes from his reported position. This undesignated galaxy is noted (by Zwicky) as magnitude 15.4 and compact (2000 position: 15h20.6m, +1°49′).

If you have a very large telescope and dark skies, study the area around M5 carefully. M5 is projected on the eastern edge of an enormous nearby cloud of galaxies, an outlying part of the Virgo supercluster. Zwicky calls this galaxy cluster 1510.0 + 0315 (its approximate central coordinates) and says he found 2295 members. Many of these should be barely visible under perfect conditions.

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Double Stars

Exploring the Doubles of Libra, the Balance

by Glenn F. Chaple, Jr.

Libra is one of those constellations that offer little to the naked eye, but hold many items of interest to telescope users. For openers, try **Alpha** (α) **Librae** — preferably using your finderscope or a pair of binoculars, as the component stars are separated by nearly 4 arcminutes. Hard to believe that so a wide pair could be physically bound, isn't it? But studies show that these stars, 65 light-years away, are traveling together through space; their true separation is about 450 billion miles.

Much, much closer is **Mu** (μ) **Librae**, which lies 2° north of Alpha. This magnitude 5.8 and 6.7 duo is just 1.8″ apart — right at the limit of resolution of a 2.4-inch (60mm) refractor. When the Russian astronomer F. G. W. Struve conducted a double star search during the mid-1820s, he surveyed the skies north of −15° declination. Although Mu lies a degree north of his southern limit, Struve still failed to pick it up. When Vermont-born Sherburne W. Burnham discovered Mu's duplicity a half century later, the two stars were 1.4″ apart — almost half an arcsecond closer than they are today. Perhaps they were even closer when Struve swept past them.

Struve did log a handful of double stars in Libra, and two — **Σ1962** and **Σ1966** — are rather attractive sights for modest-sized telescopes. The first of these is, in fact, the prettiest double star in Libra — a matched set of magnitude 6½ gems set 12 arcseconds apart. Each has a spectral class of F8, so they may appear slightly yellowish. The component stars of Σ1966 are also evenly matched, but about 3 magnitudes fainter. To find this dim twosome, search an area about 2½° southeast of Σ1962. I stumbled upon Σ1966 on the night of May 22, 1976, while tracking the asteroid 1580 Betulia with my 3-inch reflector. Σ1966 isn't mentioned in *Burnham's Celestial Handbook*, but it does appear in Webb's *Celestial Objects for Common Telescopes*. While the latter guide is quite out of date, having been compiled about a century ago, it does list a number of double stars ignored by Burnham. For this reason, I highly recommend it as a supplement to Burnham's.

Three more Struve pairs in Libra may be scooped up by small scopes. The brightest of these is Σ1899 — an unequal magnitude 7 and 9.5 pair located about two degrees northeast of 16 Librae. If you can't see the companion star, try averted vision and a magnifying power of at least 60x. By the way, Robert Burnham Jr. wins back a point with this double. He lists it; Webb doesn't.

But neither Webb nor Burnham includes Σ1847 and Σ1914 in their guides. I managed to cull these double stars from the pages of the Lick Catalogue. **Σ1847** is made up of two 9th magnitude suns that appear to be optically aligned. They were 18.7″ apart in 1829 and 28.0″ from each other a century later. You'll find this double 2° northeast of 2 Librae and just 10 arcminutes due south of a 7th magnitude field star. A bit harder to find is **Σ1914**, which lies in a rather barren region 4° north and slightly west of Beta (β) Librae. This relatively fixed double sports components of magnitudes 8.5 and 9.2, separated by a spacious 31 arcseconds. To me, the challenge of a faint double star is in finding it. If you can locate Σ1899, Σ1847, and Σ1914 without setting circles, you can track down just about any sky object the heavens offer.

Iota (ι) **Librae** (Hh 465) has a 9th magnitude traveling companion nearly one arcminute away. The "Hh" designation means that Iota was originally catalogued by William Herschel (H) late in the 18th century, and was recatalogued a few decades later by his son, John (h). Each of Iota's stars is a close double, but only the B star (= β618; mags. 10, 10.5; sep. 1.9″; p.a. 17°; 1943) falls within the range of amateur scopes.

There are two other "Herschel-herschel" doubles near Iota Librae. **Hh 467** is an easy magnitude 7 and 8 pair, found 1½° north of Iota. You won't find Hh 467 in *Burnham's* because it's listed there as Shj 195. This designation shows that the pair was catalogued during a survey done by James South (S) and John Herschel (hj) in the 1820s. Howzat? Well, y'see, William Herschel (H) catalogued it first. Then his son, John (h), recatalogued it (Hh 467). Then John Herschel (hj) and James South (S) . . . Don't blame me for the confusion — I just report facts!

The other Hh double (**Hh457**) is found about 40 percent of the way from Sigma (σ) to Alpha Librae. Here is a double star whose spectral classes (K5 for the main star, M0 for its partner) promise an interesting color contrast. When I first viewed Hh 457 eight years ago, poor seeing allowed me to note only that the primary star had a ruddy appearance. I'd be interested in knowing what colors you see. Although the stars of Hh 457 share a common proper motion, one star is outracing the other. Their separation is now twice what it was in 1823.

The 179th double star catalogued by South and Herschel during their cooperative survey was an attractive pair of roughly equal stars, separated by 35 seconds. You'll rarely see it identified as Shj 179, however. In 1875, S. W. Burnham resolved the westernmost component of Shj 179 — thus most sources now call the entire system **β225**. If you own a small telescope, be content to enjoy the wide pair South and Herschel catalogued. Those of you with 6- or 8-inch scopes might want to try your luck with Burnham's pair, whose magnitudes are about 7.5 and 8.5. In 1955, these slow-moving stars had a separation of 1.2″, with the secondary situated east of the main star.

A pair that is undisputedly S. W. Burnham's is **β122**, which forms a tight triangle with Kappa (κ) and 41 Librae.

Star	R.A. (2000)	Dec.	Mags.	Sep.	P.A.	Year
Mu (μ) (β106)	14h17.3m	−14°11′	5.8, 6.7	1.8″	355°	1958
Shj 179 (β225)	14h25.4m	−19°57′	6.4, 6.8	35.1″	296°	1955
Σ1847	14h28.7m	−10°13′	9.1, 9.3	28.0″	264°	1925
Alpha (α) (Shj 186)	14h50.9m	−16°02′	2.9, 5.3	231.0″	314°	1913
Hh 457	14h57.3m	−21°23′	5.9, 8.2	21.8″	302°	1959
Σ1899	15h01.6m	−03°10′	7.0, 9.5	28.2″	67°	1937
Σ1914	15h11.8m	−05°28′	8.5, 9.2	31.1″	336°	1915
Iota (ι) (Hh 465)	15h12.3m	−19°47′	4.7, 9.4	58.6″	111°	1943
Hh 467 (Shj 195)	15h14.4m	−18°26′	7.1, 8.1	47.0″	140°	1916
Lalande 123 (S693)	15h33.2m	−24°29′	7.1, 7.1	9.2″	300°	1951
Σ1962	15h38.7m	−08°48′	6.5, 6.6	11.9″	188°	1958
β122	15h39.9m	−19°46′	7.2, 7.4	1.7″	221°	1966
Σ1966	15h42.0m	−11°09′	9.3, 9.3	22.9″	52°	1918

Compared to most Burnham pairs, which are either extremely close or differ greatly in brightness, this pair is a piece of cake. Theoretically, a good 3-inch telescope should reveal the 1.7″ gap separating these magnitude 7.2 and 7.4 suns. More realistically, you may need a 4- to 6-inch scope and good seeing to notch it.

Roughly 2° west of 42 Librae is our final pair — **Lalande 123**. Among the double stars in Libra, it ranks second only to Σ1962. Like Σ1962, it is a twin double — both stars being about 7th mag. A 9-second separation means that even the small-telescope owner can appreciate its beauty. The more westerly member of Lalande 123 is a close binary pair with a period of 57 years.

DOUBLE TAKES: Bill Anderson and Steve Coe have recently completed a *Catalog of Multiple Stars Brighter than 12th Magnitude North of −40° Declination*. They give data for over 600 pairs and multiples, including the 100 I recently featured in a four-part series in this magazine. All are listed by constellation, and *Sky Atlas 2000* owners will be pleased to learn that coordinates are given for the year 2000. Don't let the "12th mag" part of the title trip you up — most of the catalog entries are brighter than 7th magnitude. You can get a copy of this useful catalog for $8 dollars from: The Basics Co., Box 16131, Phoenix, AZ 85011.

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Variable Stars

A Midsummer Night's Dream

by David H. Levy

Summer observing! Those memorable warm nights of pleasant watching, the nights where we can stay up late — or even all night — looking at the stars we love under practically ideal conditions. And there is more — in summer, we have a veritable cornucopia of variables to enjoy, observe, and learn from.

Summer is when the Milky Way is brightest and most prominent, and since most of the stars in our Galaxy lie on the plane of the Milky Way, it stands to reason that most of the variables would be there, too.

Many variable star observers consider 213843 **SS Cygni** the most interesting star for summer observing. A "dwarf nova," SS Cyg is an interacting binary in which a red giant transfers matter to an accretion disk circling a white dwarf. Losing orbital velocity through friction within the accretion disk, the matter then spirals inward to the dwarf. The consequent buildup of material (hydrogen and some helium) eventually reaches a critical point, where it ignites in a flare. This causes an outburst that makes the star's brightness jump from its usual 12th magnitude to around 9th magnitude in a day or two. Though quite irregular, each dwarf nova has an approximate period. SS Cygni's is about average: roughly 50 days. But I have observed this star over several years, and have seen the time between maxima vary from as little as 14 days to as long as 3 months. You should check out this star every clear night.

Early this summer, before Cygnus rises too high in the evening sky, you'll be able to catch another cataclysmic variable, 094512 **X Leonis**, as it slips westward. This star is easily found because it is less than a degree away from the famous Mira-type star, R Leonis. X Leo is very faint at minimum, its brightness being a bare 15.1 magnitude. But its maximum brightness reaches 12th magnitude — where it should be visible in any scope of 6-inches aperture or bigger.

And while on the subject of R Leonis, you still should be able to see it during the early summer. Try looking for it first, and then when you have made your estimate, move over to X Leo and see if you can find it. Even if you can't see X Leo, record the magnitude of the faintest star that you see. Such observations are valuable, for cataclysmics have the happy habit of staying at their minimum unless they are going into outburst. In fact, if a dwarf nova rises more than 0.5 magnitude above its usual minimum, you can be pretty sure it is going all the way to outburst. Thus, even if you simply note "X Leo = (13.7" — meaning that X Leonis was fainter than 13.7 magnitude — you will have noted a useful fact.

Unless your telescope has an aperture greater than 10 inches, you may not see X Leo at minimum. But sooner or later it will eventually put on a celestial show for you, especially since its period averages some 23 days. But remember: after you spend an easy minute getting R Leo, neighbor X Leo is a different "kettle of star" and can be quite difficult.

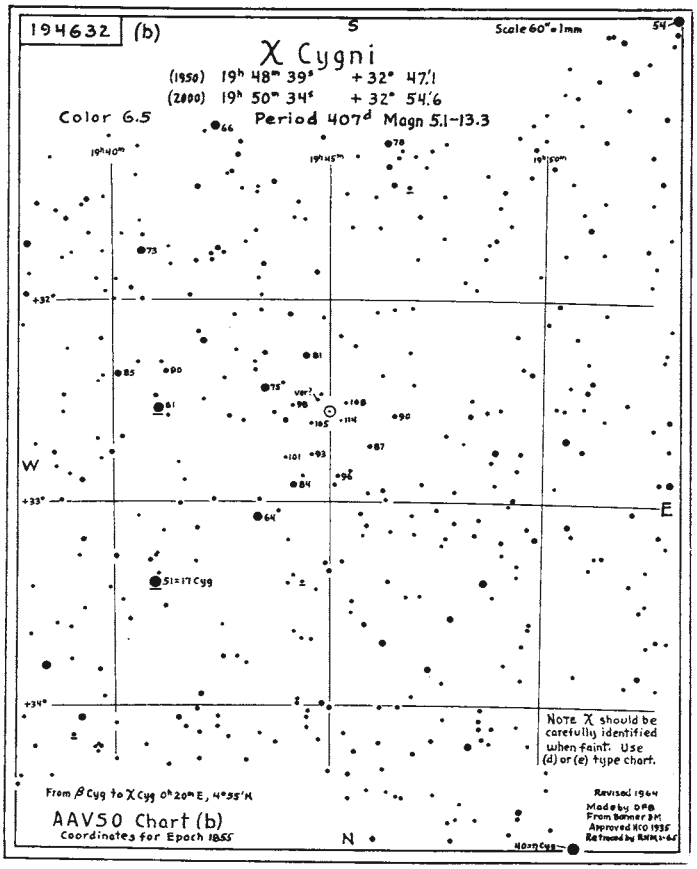
Let's now move toward the east, and explore a different region. Lyra has a number of fascinating variables, beginning with 185243 **R Lyrae**, a Mira-type variable whose 4.0 to 5.0 range makes it an easy target for binoculars. But beware of one potentially serious difficulty with R Lyr, which develops from its strong red color. The "Purkinje effect" — a long-known but somewhat controversial effect, during which red light builds up in your retina and causes a red star to brighten appreciably as you stare at it — is especially strong with this star.

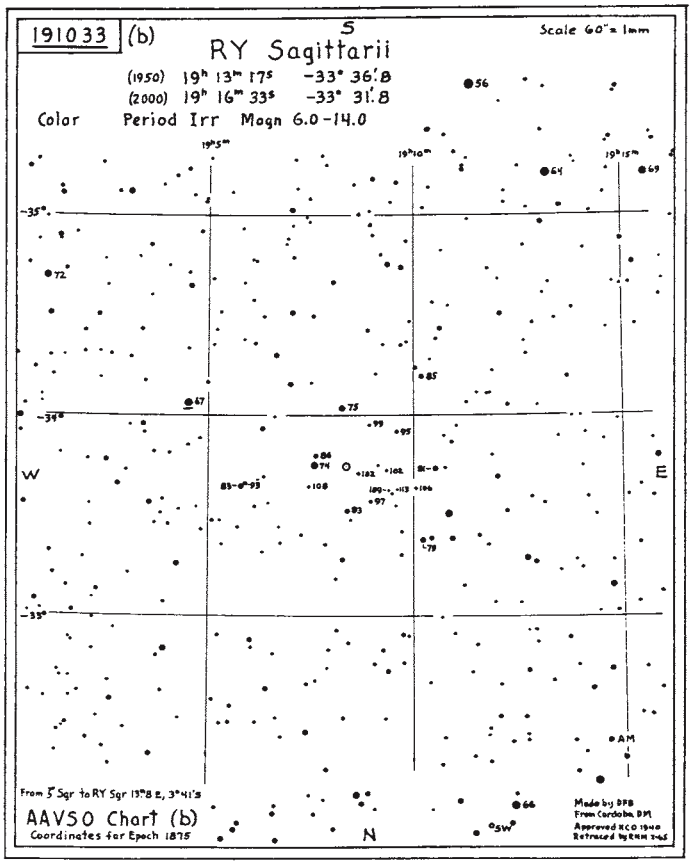
Theoretical studies have shown that the Purkinje effect is not a genuine problem. But many variable star observers will swear that it is, and that it cannot be ignored if they are to have confidence in their work. The easiest way to avoid the effect is simply to look at the star with quick glances. If you avoid prolonged stares, your estimates will be more accurate. We shall look at another very red star later.

In Lyra, there are some curious, if more traditional, long-period variables like 184134 **RY Lyrae**. RY is one of the more interesting Mira stars in Lyra, partly because it is not adequately observed. Its easily-found star pattern near Beta (β) Lyrae is a lot simpler to identify than the often-faint variable itself. RY's 9.0 magnitude maximum is easy to watch, but its minimum sinks to 15th magnitude or deeper. In any case, it has often been on the AAVSO's list of stars that need more observation, and so I am including it on the program here.

Moving back into Cygnus, we encounter one problem: to think about observing all its variables is to face a total of more than 1,500 stars! In this one constellation, there's more than enough to fill a lifetime. Since we can hit only the "high spots," let's begin with 194632 **Chi** (χ) **Cygni**, a Mira-type star whose 8-magnitude range is one of the most dramatic of all. Without checking any predictions, try looking at the sky tonight, down the long neck of the Swan. Is there an "extra" star near Eta (η) Cygni? For about six weeks of every cycle, Chi is brighter than 6th magnitude, meaning that under a dark country sky it just reaches naked-eye brightness. Because Chi has been known to get as bright as 3.3 magnitude, it has sometimes been advertised as a fine object for beginning variable star observers.

It isn't. In fact, the fainter Chi gets, the more difficult it becomes because of its location in the center of one of the richest parts of the Milky Way. If Chi lies in the midrange of its cycle, about 9th or 10th magnitude, the star isn't too difficult to find. But when it drops down to 12th and 13th magnitude, locating Chi becomes a real headache. When I first decided to find Chi Cygni, I spent


194632 (b)
χ Cygni
(1950) 19h 48m 39s +32° 47'.1
(2000) 19h 50m 34s +32° 54'.6
Color 6.5
Period 407d Magn 5.1-13.3
Scale 60" = 1mm
Note χ should be carefully identified when faint. Use (d) or (e) type chart.
From β Cyg to χ Cyg 0h 20m E, 4°55' N
AAVSO Chart (b)
Coordinates for Epoch 1855
Revised 1964
Made by DPB
From Bonner DM
Approved HCO 1935
Retraced by RMH 1-65



A beginner's star? Chi Cyg can be difficult even for experienced observers. RY Sgr "drops out" from time to time. Charts courtesy Janet A. Mattei, AAVSO.

two frustrating hours under a suburban Montreal sky trying to find it and make an estimate. It was one of the most intimidating experiences of my observing life, because I had been led to believe that Chi Cygni was a "beginner's star." So be forewarned!

There are other stars in Cygnus which, though not quite as famous, are well worth a beginning observer's time. First, let's look at 193449 **R Cygni**, a standard Mira star. With a maximum of 6.5 and a minimum of 14.2, a period of 426 days, and an amplitude of almost eight magnitudes, this star offers considerable excitement for summer nights.

Then there is 200938 **RS Cygni**, a star not too difficult to find for two reasons. First, it lies close to Gamma (γ) Cygni in the middle of the Swan and, second, it is one of the reddest stars in the entire sky. With a maximum magnitude of 6.5 and a minimum of 9.3, RS has some similarity to the semi-regular class. Also, remember what I said earlier about the Purkinije effect? This star personifies it! But don't let concern about the effect prevent you from adding the star to your program. Ultra-red stars are very beautiful to watch and a challenge to estimate, even if the scientific value of your estimate is questionable.

Star	Maximum	Minimum
R Leo	Dec. 16	July 31
RY Lyr	Sept. 11	May 1
χ Cyg	May 20	Jan. 5, '85
R Cyg	Aug. 3	March 5
RS Cyg	Nov. 12	April 4
Z Cyg	Sept. 7	May 7

Cygnus is full of other variables; among the more popular are 195849 **Z Cygni** and the semi-regular star 213244 **W Cygni**. W is close to SS Cygni, and can be observed at the same time, with the proviso that as a semi-regular, W Cyg should be watched but once or twice a month.

Of the more than 1500 variables in Cygnus, two are of special interest. 201437 **P Cygni** is a bright star with nova-like properties, quite irregular and well-worth watching. First noted around 1600 A.D., it was recorded at third magnitude. And according to the *General Catalogue of Variable Stars*, this star has varied by at least five magnitudes since the 18th century. And there is another, **V1500 Cygni**, a true nova which is theoretically still visible almost a decade after its outburst on August 29, 1975. Nova Cygni, appearing as a bright magnitude 1.7 "extra star" on the long arm of the cross, was well observed and recorded by backyard astronomy enthusiasts all over the world. I stopped observing it two years ago when it could still be seen at magnitude 15.5. Those of you with 16-inch or larger telescopes may still try to see this famous star, which stole the show during the summer of '75.

Let's end our tour by visiting one of the more than 2400 variables in Sagittarius, 191033 **RY Sagittarii** (underlining the last two figures means it has a southern declination). This R CrB-type star usually sits at its maximum of 6.5, but occasionally plunges to a minimum around 14.0. I have always felt a special enthusiasm for these mysterious R CrB stars — but in a poetic, unscientific sense. In their dark plunges to minimum, they show us a side of themselves that somehow reflects our own condition as humans. Something in their chemistry forces them to "fall back and regroup," a necessary process that later enables these stars to return and shine with the full glory of which they are capable.

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Scanning the Literature

Both the *Astronomical Journal* (*AJ*) and the *Astrophysical Journal* (*ApJ*) began publishing in a somewhat larger format at the start of the year. The *ApJ* doesn't seem to have gotten any thinner despite the fact that papers take up fewer pages. The *AJ*, for its part, boasts a cover in blue ink featuring a diagram or photo from one of the articles contained in each issue. You might suppose that a young astronomer trying to establish a reputation will now know he's arrived when his/her paper makes the cover of the *AJ*, just as when a rock group gets their picture on the cover of *Rolling Stone*! The new cover and other changes in the design of the journal are the legacy of George Abell, who assumed editorship the very week of his untimely death last October. Paul Hodge of the University of Washington has been chosen as the new editor of the journal.

A comprehensive three-paper series by Australian Elaine Sadler provides baseline information on a large number of galaxies ("Radio and Optical Observations of a Complete Sample of E and SO Galaxies. I. Radial Velocities. II. UBV Aperture Photometry. III. A Radio Continuum Survey at 2.7 and 5.0GHz"; *AJ* **89**:23-63 January). Two hundred forty-eight galaxies south of declination −12° were observed, many for the first time other than to be included in a catalogue. These results help fill a large gap of basic data for southern galaxies.

The best amateur photographs of Messier 104 show a number of tiny yet fuzzy spots around the periphery of this galaxy. Most of these are not faint background galaxies but members of the globular cluster system belonging to M104. This system has now been studied by William E. Harris, Hugh C. Harris, and Gretchen L.H. Harris in "Globular Clusters in Galaxies Beyond the Local Group. III. NGC 4594 (The Sombrero)" (*AJ* **89**:216 February). The authors counted images on plates taken with the 4-meter telescopes at Kitt Peak and Cerro Tololo, looking for an excess of images around the galaxy. Taking into account background galaxies and foreground Milky Way stars, the Harris' find a total of about 1200 globulars to V magnitude 23. No photometric measures of individual objects were made, so the magnitudes of the clusters are not known. However, from arguments about their brightness distribution and the somewhat uncertain distance to the galaxy, the brightest globulars in M104 are about magnitude 20.

Two related articles appeared in *ApJ* recently, both dealing with NGC 5128. Observations reported in "The NGC 5128 Globular Cluster System" by James Hessner, Hugh Harris, Sidney van den Bergh and Gretchen L.H. Harris (*ApJ* **276**:491, January 15) brings to 20 the total of spectroscopically confirmed globulars in this nearby galaxy. The brightest among them are similar to or slightly larger and brighter than ω Centauri, the most massive and luminous globular cluster in the Milky Way. The twenty studied objects range in magnitude from V=17.0 to 18.7 — not visible in amateur telescopes, but photographable with apertures as small as 8 inches. A finder chart is provided in the article if you want to try for them. The authors also made a preliminary search for more clusters by counting images on UK Schmidt plates much as they did for M104. They found that NGC 5128 possesses a substantial system of perhaps 600 clusters. Considering none at all were known prior to 1980, this is progress indeed.

Infrared observations of these objects have been made by Jay Frogel, and are discussed in "The Stellar Content and Metallicity of NGC 5128 Globular Clusters" (*ApJ* **278**:119, March 1). He compared the IR properties of 12 of the known objects with clusters in the Milky Way and the Large Magellanic Cloud. The NGC 5128 clusters are red, metal-poor objects like those typical of our Galaxy, and are not young "blue" globulars like those in the LMC.

A new globular cluster has been added to the roster in our Milky Way ("AM-1: A Very Distant Globular Cluster", Marc Aaronson, Robert Schommer and Edward Olszewski; *ApJ* **276**:221, January 1). Photometry based on deep CCD frames confirm this southern object as a globular cluster. The derived distance is 118 kpc, placing it among the most distant known clusters (or anything else!) likely to be associated with the Galaxy. The brightest members stars are about V magnitude 18, while the integrated magnitude (within 2′ diameter) is about 15.

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NGC 5128: *600 red, metal-poor globulars.*

Variable star observers may be interested in a review paper by J. Smak entitled "Outbursts in Dwarf Novae" (*PASP* **96**:5, January). Dwarf novae, like all cataclysmic variables, are close binary systems, containing in this case a white dwarf and a cool main-sequence star. Material flows off the cool companion, and before reaching the surface of the white dwarf forms an "accretion disk" around it. As a result of thermal instabilities, this disk intermittently brightens the system by two to six magnitudes within a few hours. Smak notes that "a real wealth of information on the light variations of dwarf novae is now available, principally due to the effects of many amateur visual observers." While the basic mechanism of how outbursts occur is well understood, the author points out that extensive two-color photoelectric photometry of a few objects would help constrain refinements in a complete theoretical treatment. Since there are many bright dwarf novae, and because the stars need to be monitored on a continual basis, it may again be amateurs who provide the necessary data to tie up the remaining questions about these objects.

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The Sombrero Galaxy: *1200 globulars orbit this Virgo giant.*

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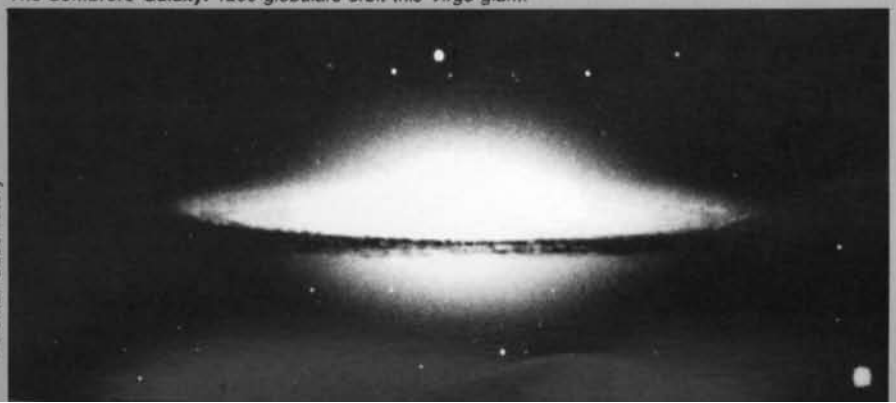

Spiral Galaxy NGC 6946

Kitt Peak National Observatory photo